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Resource and Land Investigations (RALI) Program: Considerations in Evaluating Utility Line Proposals

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JULY 1975

PREPARED UNDER CONTRACT FOR
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

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ABSTRACT

Considerations involved in evaluating the location of a proposed utility line and its probable environmental impact are presented. The principal environmental factors are analyzed, together with the technical variables involved in constructing electric transmission lines and pipelines. The legal requirements that generally must be met at the various governmental levels are summarized. Considerations affecting shared or multiple use of a utility corridor are addressed. A set of case studies illustrates methodologies available to utilities in locating lines.

FOREWARD

This report presents in draft form a set of considerations prepared under the Resources and Land Investigations (RALI) Program of the United States Department of the Interior for use in evaluating proposals for the location of electric transmission lines and pipelines. The considerations are intended to summarize the principal environmental and technical influences on the routing of utility lines and to discuss how these factors interrelate with the criteria used to determine selection of an appropriate location.

The considerations are primarily intended for use by field personnel of the Bureau of Land Management, Department of the Interior, whose responsibilities include evaluation of the impact of proposed utility lines across public lands and determination of whether to issue permits required for such land usage. The present report provides a vehicle to facilitate distribution of the draft version of the considerations by the Bureau of Land Management for review by appropriate officials both within and outside of the Department of the Interior. Following such review, the considerations will be revised to reflect comments obtained.

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GLOSSARY

ALTERNATING CURRENT (ac)	An electric current that reverses its direction of flow periodically as contrasted to direct current.
AMPERE	The unit of electric current produced by one volt applied across a resistance of one ohm.
ANGLE SUSPENSION TOWERS	Transmission towers used at points where the power line deviates from a straight line at an angle.
AQUIFER	Porous soil lying between impermeable strata to which water may move, yielding groundwater for wells and springs.
ARTESIAN AQUIFER	Porous soil lying between impermeable strata in which water moves under pressure yielding groundwater for wells.
BEDROCK SUBSIDENCE	Soil compaction due to the collapse of cavern ceilings and down warping of overlying rock structures.
BIOMASS	The total weight of organisms (living and dead) per unit area, determined during a specific time period.
BIOTA	The fauna (animals) and flora (plants) of a region.
BIOTIC PROVINCE	A continuous area of land characterized by specific features of physiography, soil, climate, flora and fauna.
CALDERA	A large basin shaped volcanic depression, more or less circular in form, that forms due to the collapse, explosion or erosion of a volcanic cone.
CALICHE	A surface deposit that consists of sand or clay impregnated with crystalline salts, such as sodium nitrate or sodium chloride.

CARNIVORE	A flesh-eater. In a narrower sense a member of the order carnivora of placentental mammals containing forms such as cats, wolves, bears and seals.
CATHODIC PROTECTION	The principle of supplying an electric current flowing through the soil towards a pipe from an outside source to prevent corrosion of the pipe.
CHAPARRAL	Low, often dense, scrub vegetation characterized by shrubs or dwarf trees.
CIRCUIT	A combination of interconnected devices forming a closed path over which electric current is intended to flow.
CIRCUIT BREAKER	A switch that automatically opens an electric circuit carrying power when an abnormal condition occurs.
COFFERDAM	A water-tight temporary structure for keeping the water from an enclosed area that has been pumped dry.
COMMON CARRIER	A company recognized by an appropriate regulatory agency as having a vested interest in furnishing communications services or in transporting commodities such as gas, oil or electricity.
CONDUCTOR	A component of an electric line over which current flows.
CONIFEROUS TREES	A cone-bearing tree such as a pine, spruce, fir, yew, etc.
CORONA	A discharge, which is often luminous, at the surface of a conductor or between two conductors of the same transmission line. It is accompanied by ionization of the surrounding atmosphere and power loss.
CORRIDOR	A stretch of land generally a few miles wide within which one or more utilities may be planned.

GLOSSARY (Continued)

CRYOGENICS	A branch of physics relating to the production and effects of very low temperatures.
CRYOGENIC TRANSMISSION	Electric transmission over a conductor the resistence of which has been drastically reduced by cooling to a very low temperature (as low as -269°C).
DEAD-END TOWERS	A transmission tower generally employed for a deviation of a power line at a large angle from a straight line. On dead-end towers, the conductors are fastened rigidly to the structure.
DECIDUOUS TREE	Tree that sheds its leaves at certain seasons.
DESERT PAVEMENT	Soil surface that is composed of large grained sand and pebbles not readily transported by wind.
DIRECT CURRENT (dc)	Electricity that flows continuously in one direction as contrasted with alternating current.
DISTRIBUTION LINES	Electric power lines of 69 kilovolts (kV) or less.
DOUBLE DITCHING	The process in which topsoil is maintained separately from the remainder of the soil excavated during construction. This procedure is utilized most frequently in regions where the topsoil is fragile or where the subsoil is undesirable.
ECOLOGY	The study of the interrelationships of organisms to one another and to the environment.
ECOSYSTEM	Ecological system formed by the interaction of coacting organisms (life forms or biota) and their environment (physical factors or abiotic factors).
ECOTONE	The boundary or transitional area between two adjacent biological communities which exhibits competition between the organisms common to both.

EDAPHIC	Pertaining to the soil.
EDGE EFFECT	The influence of two biological communities upon their adjoining margins or fringes, affecting the composition and density of the population in these bordering areas. (See Ecotone).
E_H or E_{Redox}	The reduction potential (or "Redox" potential) of a chemical system; a measure of the tendency for reduction reactions to occur.
ELECTROCHEMICAL REACTION	A chemical reaction in which a current of electricity causes or sustains the action.
ELECTROMAGNETIC INTERFERENCE	Any electrical or magnetic disturbance which will change or modulate a received signal, usually applied to disruption of radio or TV signals.
ELECTROMAGNETIC NOISE	Noise, often manifested as static, in a communications system.
ELECTROSTATIC	Pertaining to stationary as opposed to moving electric charges.
ENDANGERED SPECIES	Those species in danger of extinction throughout all or a significant portion of their range and legally protected by the Endangered Species Act of 1973.
EPICENTER	The part of the earth's surface directly above the focus of an earthquake.
EROSION	The process of being worn away by the action of water, wind or glacial ice.
ESCARPMENT	A steep slope or long cliff separating two comparatively level or more gently sloping surfaces.
ESTUARY	An extension of the sea at the mouth of a river in which the current of the river meets the tide.

EVAPOTRANSPIRATION	The total water returned to the atmosphere from a land area by evaporation and by plant transpiration.
EXTRA HIGH VOLTAGE (EHV)	Generally used to refer to voltages of 345 kilovolts to 1000 kilovolts.
FAULT (electric)	An abnormal condition which occurs on electric power lines and disrupts normal operation.
FAUNA	The animals or animal life of a region, period or special environment.
FLASHOVER	An electric arc produced by a voltage exceeding the rating of an insulator string across which the arc occurs.
FLOCCULANT	An agent that causes the formation of aggregates of suspended particles which subsequently settle out of standing waters.
FLOOD PLAIN	A strip of relatively smooth land bordering a stream or river which is built of sedimentary deposits and which is covered with water where the stream or river overflows its banks at flood stages.
FLORA	The plant life characteristic of a region, period or special environment.
FOLIATION	A splitting into leaflike layers as with certain minerals.
FOOD CHAIN	Chain of organisms, existing in a natural community, through which energy is transferred. Each link in the chain feeds on and obtains energy from the one preceeding it and in turn is eaten by and provides energy for the one following it.
FOOD WEB	All of the interconnected dependences for food (food chains) of organisms upon others in a biological community.

GLOSSARY (Continued)

FORCED OUTAGE	The shutting down of a generating unit for emergency reasons.
GOTHERMAL AREAS	Any region characterized by the known or suspected presence of deep underground sources of hot water which may potentially be used as a source of heat and/or energy.
GROUND GRADIENT	The voltage per unit length that can be measured in the last unit of length before the level of zero potential.
GUYED TOWER	Tower supported by a tension member (a solid wire or stranded wire) to withstand an otherwise unbalanced force on the tower.
HABITAT	The total environment occupied by an organism or population of organisms.
HARDWARE DISEASE	Term used by the Bonneville Power Administration to describe the harmful effects of ingestion of bolts and other small metal construction objects by ruminants and other grazing animals.
HERBIVORE	A plant-eater.
HIGH VOLTAGE (HV)	Generally used to refer to voltages less than 345 kilovolts.
HUMUS	Organic matter within the soil.
HYDRAULIC PLANTING	Reseeding of exposed soils by means of a pressurized stream of water.
HYDROLOGY	A science dealing with the properties, distribution and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

GLOSSARY (Continued)

INSULATOR STRING	A string of procelain units in series which support the conductors on transmission towers and insulates them from electrical ground. These units may be in a vertical, horizontal or a vee string configuration or arrangement.
INTERTIE	A transmission line joining two or more power systems through which power produced by one can be used by the other.
ISO-ERODANT MAP	A map with lines connecting points of equal erosion potential.
ISOKERAUNIC MAP	A map depicting contours of equal thunderstorm frequency.
JACKING	A method of emplacing a pipeline beneath a waterway by either forcing the pipe through the ground without prior tunneling or by forcing it through a tunnel or pit.
KINEMATIC VISCOSITY	The absolute viscosity of a fluid divided by its density. Also known as the coefficient of kinematic viscosity.
LATTICE TOWER	A tower fabricated from many structural members (usually angle sections) by lacing between members. Also called laced tower since members are "laced" together.
LINE OUTAGE	The de-energization of a transmission line whereby both voltage and current are reduced to zero, and power ceases to be transmitted.
LIQUID LIMIT	The water content expressed as a percentage of the dry weight at which a soil mass just starts to become fluid under the influence of a standard series of shocks.
LITTER	Organic matter on the soil surface.
LOAD	The amount of power needed to be delivered at a given point on an electric system.

LOAD CENTER	The point at which the loads of a given area are assumed to be concentrated for purposes of analysis.
LOOPING	Paralleling one pipeline with other pipelines, all of which serve the same liquid or gas source and destination.
MEAN ANNUAL BIOTEMPERATURE	The average of the monthly mean temperatures above $0^{\circ}C$.
MERCALLI SCALE	A relative scale to measure the intensity of an earthquake.
Mho	The unit of electric conductance equal to the reciprocal of the ohm.
MULTIPLE CIRCUIT TOWER	A tower capable of supporting more than one circuit. Usually refers to more than two circuits.
MULTIPLE USE	Utilization of a utility right-of-way for various non-utility purposes, such as farming or recreation, as well as for utility lines.
NOISE	Unwanted sound, either audible or in the form of electromagnetic interference with communications signals.
NON-SPECULAR	Having a flat or non-light reflecting surface. Used primarily in reference to transmission lines, towers and conductors.
Ohm	The unit of electric resistance equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.
OMNIVORE	An eater of both plants and animals.
OUTAGE	The period in which a generating unit, transmission line, or other facility, is out of service.

PEDOLOGY	A science dealing with the study of soils.
PERMANENT OUTAGE	A result of a fault accompanied by some damage to insulation or structure of a line component so extensive that transmission cannot continue.
PERMEABILITY	The property or condition of the soil that relates to the passage of water through it.
p^H	A quantitave expression for acidity or alkalinity of a solution or soil.
PHASE CONFIGURATION	The configuration of the separate conductors carrying the distinct phases (voltages) of a 3-phase alternating current line.
PHASE SPACING	The spacing between the conductors carrying the distinct phases (voltages) of a 3-phase alternating current line.
PHOTOGRAMMETRY	The art or process of surveying or measuring from photographs, especially aerial photographs.
PHOTOSYNTHESIS	Conversion by green plants of inorganic material and nutrients from soil and water into organic nutrients to sustain life.
PHYSIOGRAPHIC PROVINCE	Land classification in terms of common terrain, geology, climate, soils, vegetation, land use, etc.
PIPELINE	A line of pipe with pumps, valves and control devices for conveying liquids, gases or finely divided solids (slurries).
PLASTIC LIMIT	The water content expressed as a percentage of the dry weight at which a soil mass becomes brittle and ceases to be plastic.
PLASTICITY INDEX	The range of water content expressed as a percentage of the dry weight within which a soil mass is in a plastic or semi-solid condition. It is the difference between the liquid limit and the plastic limit of a soil mass.

POTHEAD	A device used to seal the end of a cable and provide an insulated egress for the conductor or conductors.
RAPTOR	A bird of prey such as an eagle.
RICHTER SCALE	A scale to measure the energy released during an earthquake, as determined by the amplitude of surface waves. It indicates the magnitude of an earthquake at its epicenter. A Richter magnitude 9 earthquake would be approximately equal to a Mercalli intensity XII earthquake, and would cause total damage.
RIGHT-OF-WAY (ROW)	The actual land within a corridor which is dedicated to line use, either by lease agreement or outright purchase.
RIPARIAN	Land bordering a stream, lake or tidewater.
SCOUR	The action of a flowing liquid as it lifts and carries away the material on the sides or bottom of a waterway, conduit or pipeline.
SEISMIC	Caused by an earthquake or other earth vibration.
SHARED USE	Use of a common corridor by two different utility rights-of-way serving distinct purposes such as highway, transmission line, pipeline, etc.
SHRINK-SWELL POTENTIAL	The change in volume of a soil mass to be expected with a change of water content.
SINGLE CIRCUIT TOWER	A tower capable of supporting only one circuit.
SLURRY	A watery mixture of an insoluble substance such as coal.
SLURRY PIPELINE	A pipeline which transports a commodity such as coal in pulverized form suspended in water.

SPAN	Horizontal distance between adjacent supporting points of a conductor.
STEREOSCOPIC PHOTOGRAPH	A photograph produced by a camera in which two narrowly-separated lenses record simultaneous images for use in a viewing system to give a three-dimensional impression.
SUBSIDENCE	A local mass movement that involves the gradual downward settling or sinking of the solid earth's surface with little or no horizontal movement.
SUPERCONDUCTING TRANSMISSION	Electric transmission over a system using superconducting metals (such as niobium plated on copper) cooled to a very low temperature.
SWAGE	A device used in underground connection for joining two different size pipes.
SWAMP SHOES	Metal braces sunk deeply in the ground used to stablize foundations in swampy, boggy land.
SYSTEM VOLTAGE	The highest effective voltage between any two conductors of a circuit.
TALUS	A sloping mass of rocky fragments at the base of a cliff or other steep slope.
TANGENT TOWER	A transmission tower used over straight stretches of a power line. At their point of contact with the tower, the conductors are tangent to the insulators suspended from the tower.
TAP	A connection from one transmission line to another or to a substation.
TECTIONISM	The set of natural process related to the creation, movement, and subsequent deformation of the Earth's crust.
TEMPORARY OUTAGE	A result of a fault on an electric power line that can be rectified by de-energizing the affected component through circuit breaker or other switching action.

THREATENED SPECIES	Those species likely to become endangered within the foreseeable future throughout all or a significant portion of their range. Threatened species are legally protected by the Endangered Species Act of 1973.
TOPOGRAPHY	Characteristics of ground surface such as plains, hills and mountains; degree of relief, steepness of slopes; and other physiographic features.
TOTAL DISSOLVED SOLIDS (TDS)	A measure of the aqueous concentration of salts leached from rocks and soils as well as dissolved pollutants introduced by man, such as fertilizers or heavy metals.
TOTAL SUSPENDED SOLIDS (TSS)	A measure of the material, generally derived from erosion, being carried by a stream or river as fine particles.
TRANSMISSION LINE	A line of structures and conductors used for transporting electrical power at 69 kilovolts or more.
TRANSMISSION SYSTEM	An arrangement of transmission lines, substations, and generating stations used for delivering electric power.
TURBIDITY	A condition of a water body containing suspended material such as clay or silt particles, dead organisms or their parts, or small living plants and animals.
ULTRA HIGH VOLTAGE (UHV)	Generally used to refer to voltages of 1000 kilovolts and higher.
VIEWSCAPE	All elements, natural and manmade, that may be seen with the naked eye from a given vantage point.
VISCOSITY	The property of a fluid that resists forces that would cause it to flow.
VOLCANISM	Volcanic power or action.

VOLT	The potential difference and electromotive force between two points in a conductor carrying a constant current of one ampere across a resistance of one ohm.
VOLTAGE	The electric potential or potential difference expressed in volts.
VOLTAGE GRADIENT	Intensity of an electric field usually expressed in kilovolts per centimeter (kV/cm).
WATER BARS	Structures placed to divert runoff and control erosion.
WINDROWING	The practice of gathering into a long, narrow pile or "windrow" - i.e., a row resembling one helped up by the wind.
YARDING	The removal of trees or tree parts from an area with a minimum of soil surface disturbance.

SECTION I
INTRODUCTION

SECTION I

INTRODUCTION

BACKGROUND AND SCOPE

In recognition of the need for effective land use planning (as well as water and minerals), the Department of the Interior (DOI) established a Resource and Land Investigations (RALI) Program to provide basic and interpretive data on land and its resources. The U.S. Geological Survey was designated as the lead agency for RALI in conjunction with DOI Bureaus. The MITRE Corporation has been supporting the RALI Program Office with a series of studies relating to power plant siting, utility corridor selection, and environmental assessment and reporting. This report on considerations affecting utility line proposals, developed under contract to the Bureau of Land Management (BLM), is a part of the MITRE studies in the last two of the above areas. As explained in the next subsection, however, the material is intended to be generally applicable to evaluation of utility line proposals.

The considerations are concerned with the concepts of both corridors and rights-of-way (ROW). As used here, "corridor" refers to a stretch of land envisioned as a few miles wide (typically up to about five miles, although sometimes as much as ten), within which one or more utility lines may be planned. The "right-of-way" is the actual land within a corridor on which the utility line is placed and that is dedicated to line use, either by lease agreement or outright purchase. Its width is determined by the technical requirements of the particular utility and may range from as few as 25 feet or less (for operational phase of a pipeline) to several hundred feet for an extra-high voltage (EHV) transmission line with multiple circuits.

The scope of the considerations covers lines for transmitting electric power and pipelines through which energy commodities of all types (gases, liquids, and slurry) flow. Both overhead and underground transmission lines are included. Transmission lines have been defined as those of more than 69 kilovolts (kV); lines of lower voltage are regarded as distribution lines. Pipelines considered are those at least 12 inches in diameter. No consideration is given to planning for or evaluating the impact of highways, railroads, or communications lines per se, although these are incidentally considered in Section VIII.

This report presents, in Section II, a comprehensive procedure for evaluating proposed utility lines. Sections III to VI discuss in considerable detail inclusive sets of factors that determine the environmental impacts of a line and its appropriate location.

Section VII treats laws, regulations and policies affecting line location and impact assessment; this section summarizes the principal requirements for the 11 western states of primary BLM concern. Section VIII discusses the considerations that affect the feasibility of sharing rights-of-way by different kinds of utilities and of employing a right-of-way for multiple purposes, such as recreation, agriculture, commercial enterprises, etc.

In Section IX, the methodologies available for determining the location of a utility line are considered and four selected cases involving procedures used by various utility companies (together with consultants associated with the proposed routings) are analyzed.

PURPOSE OF THE REPORT

The considerations addressed in this report have been compiled as background material for use by anyone in the government required to evaluate proposed utility lines and assess their probable environmental impact. As a RALI document, the report contains much illustrative material drawn from the experience and practice of the Department of the Interior; and descriptive data in Sections III to VII emphasize existing conditions in the eleven westernmost states, which contain the overwhelming proportion of public lands. However, it is intended that these background considerations would be generally useful in any government department, agency or commission at any level (Federal, state, or local), wherever proposed utility lines must be evaluated, the potential impacts assessed, and alternative locations compared.

The utility line planning process consists of two major phases that are essentially in the following sequence, although minor variations may occur locally. The first is the routing or corridor selection phase. In this phase, a study area is inventoried or assessed, alternative routes between points of origin and destination are laid out, and the arguments for recommending a preferred route are developed. Whether the applicant deals with a broad corridor several miles wide or with a narrower swath within which the ultimate ROW will eventually be located, this first phase culminates in the submission of an application to some regulatory body for certification as to public need and general compatibility.

The second phase begins after certification. It involves a detailed mapping and a set of studies that together lead to the exact determination of the ROW and to the preparation of a construction plan that includes the exact centerline, placement of structures, and clearance required for construction, installation, operation and maintenance. Many of the ecologic, visual, and multipurpose use questions are addressed during this second phase, when the ROW development and management plan is submitted to the regulatory body before construction begins. This two-phased sequence simplifies the certification procedure and postpones determination of many of the mini-environmental or more detailed impacts to the post-certification period. At this time, the utility must develop the details of implementation that govern how specific features of the environment will be affected.

Evaluation of proposed utility lines is a complex procedure, involving an assessment of the various ways in which the technical features of the line can affect the physical, biological, and human environments. Many variables in each of these environmental aspects must be considered, although the factors that will be influential in determining suitable location of a line and assessing its impacts will vary greatly from one situation to another. Although it is the possibility of harmful effects to the environment that generally receives the most attention, the many beneficial effects that utility lines may have on the environment must not be overlooked. For instance, in addition to the energy, power, and development of resources that they make possible both nationwide and within a locality, utility lines planned carefully can (as is pointed out in the detailed consideration of environmental factors in Sections III and following) provide specific environmental benefits including the creation of more open space, "edge" conditions favoring wildlife, and multiple uses of rights-of-way for recreational and other community purposes.

There is no way at the present time by which the various considerations addressed in this report can constitute more than convenient guidance; they cannot become regulations nor should they be viewed as providing absolute standards. Given the current state-of-the-art in impact assessment, decision-making in evaluating a utility line represents not a science but the careful application of skill and judgment to each individual case. It is likely that these conditions will continue, as is indicated by some of the case studies in Section IX. The diverse areas that must be considered cannot be represented in common units. Therefore, the overall impact of a particular location can be expressed only in such disparate terms as (for example) erosion produced, changes in water quality, wildlife affected, amounts and types of land used, and visual patterns in the landscape. Agreed-upon standards do not exist for comparing the effects of imcompatible land use or of esthetic discord to interference with aquatic biota. Thus, it becomes particularly difficult to assess alternative routes when no single route presents the best results in all respects.

Decisionmakers continue, however, to be faced with the practical need for assessing the potential impact of utility lines in terms of these diverse effects and in drawing sound and defensible tools for these purposes. One of the specific objectives of this report, therefore, is to provide a comprehensive set of data and procedures that may be used in the environmental assessment of a proposed utility line. The considerations addressed in Section II are intended to facilitate comprehensiveness in evaluating a utility line by helping to ensure that all necessary factors are taken into account and that no relevant consideration is inadvertently omitted. It is anticipated that primary use will be made of this Section, with reference to the following Sections for selected information as needed.

Sections III to VII, discussing environmental and technical factors, are aimed at providing useful background information on the variables that enter into environmental impact. In evaluating any specific utility line, the analyst or analytic team would use only a part of the contents of these sections. It is not intended to imply that a utility line as implemented is likely to produce all or even a considerable number of the possible impacts discussed. On the contrary, it may be that most utility lines produce few significant environmental impacts, as attested to by a number of the field personnel, experienced in environmental analysis, who were consulted during preparation of this report. It is important in evaluating a utility line to show the trade-offs that must be dealt with in assessing the multi-dimensional decisions about location and impacts. Often, options in the design or location of a utility line which would avoid or mitigate one type of adverse impact can be achieved only at the expense of some other disadvantage. Technical, regulatory and institutional aspects of utility lines generate requirements and impose constraints, both of which must be considered in assessing the impact and determining the location of a corridor or ROW (Sections VI and VII). Alternatives sometimes include joint use of a corridor by more than one utility and the impact may be affected by the possibilities for multiple ROW use (Section VIII). Finally, the objectives of the report include illustrative applications of different methodologies actually used in determining where to locate a utility line (Section IX).

In regard to Section IX, it should be noted that the case studies presented are not intended to imply that any of the specific approaches illustrated in the methodologies should supplant existing techniques. On the contrary, the examples were chosen as representing a wide range of methods. A particular aim was to examine some fairly novel approaches employing techniques which involve extensive quantification and use of a computer, in comparison with more established qualitative manual methods (sometimes contrasted in the same case study). Without in any way prejudicing the future role of algorithmic and computerized methods as the state-of-the-art in utility line evaluation advances, it is apparent that, while these sophisticated techniques have in some instances aided in structuring analysis, many problems remain in refining them for application. The success of all methods depends heavily on suitable means for evaluating different sets of values. Most utility lines will, for at least the foreseeable future, continue to rely heavily on constraint methods and on sound judgment concerning engineering and environmental considerations. It is not likely that there will be any substitute for the first-hand impressions that come from "walking the line."

CRITERIA USED IN ASSESSMENT

In locating a utility line or corridor, the broad goal of providing facilities that will meet the needs of users of the utility (consumers of its product) at minimal cost both in dollars and in regard to adverse environmental impact comprises many components. These components are, in the present report, termed "objectives." Objectives relate both to engineering a line and to the various ways in which the environment may be affected. Some features represent "constraints" or prohibitions on where a line can be located. How far the objectives are met and whether the binding constraints apply in a proposal for a specific line routing depend on analyzing the characteristics of the environment along a given route and the technical features of the line. These characteristics are denoted as "factors."

Objectives

An objective represents a specific aim in terms of minimizing some potentially adverse feature of location or design, or in terms of maximizing some desirable characteristic. Clearly it is desirable, for example, to minimize erosion and interference with the hydrology of a location. In addition, it is advantageous to maximize the amount of land available for public use, an objective that implies avoiding interference with lands already set aside for conservation or for public parks and encouraging the development of recreational activity such as hiking trails as part of the multiple use of a right-of-way once it is established. Engineering considerations and concern for providing services at least cost to consumers of a utility dictate such objectives as minimizing land acquisition costs and maximizing capability to expand a line as necessary to meet future needs.

Each objective relates to some general value that is to be achieved or preserved. These general values have to do with such broad considerations as ecology, land use, system economy and planning. Accordingly, in Table I-1 the objectives are itemized under a set of general values as headings.

It may be noted that, in Table I-1, objectives may concern either the broad corridor within which a line is to be located or the selection of a specific ROW in that corridor. For example,

TABLE I-1

OBJECTIVES IN CORRIDOR/ROW LOCATION*

1. ECOLOGY

    1.1 Minimize disturbance to terrestrial wildlife (birds, animals of all types)

    1.2 Minimize damage to supporting terrestrial ecology

    1.3 Protect (i.e., minimize disturbance to) rare, threatened and endangered species.

    1.4 Minimize damage to aquatic ecosystems (including plankton, other micro-organisms, invertebrates, flora, finfish, shell fish, amphibious fauna, birds and mammals depending on wetlands and/or water bodies).

    1.5 Protect (i.e., minimize use of and intrusion into) wilderness areas

    1.6 Minimize disturbance of vegetation and vegetative cover

2. OTHER FEATURES OF PHYSICAL ENVIRONMENT

    2.1 Minimize interference with hydrology

    2.2 Protect (i.e., maximize the resulting state of) water quality

    2.3 Protect (i.e., maximize the resulting state of) air quality

    2.4 Minimize erosion created

    2.5 Minimize number and extent of new access roads required

    2.6 Minimize disturbance of exceptional natural features (e.g., geologic points of interests)

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*These objectives have been assembled from a variety of sources. The aim was to collect as comprehensive a set as possible from actual practice as exemplified in environmental reports, expressed policies of utility companies, the procedures of environmental consultant firms, and criteria applied by governmental agencies at various levels. The arrangement of the objectives does not reflect anything about the relative importance of the considerations involved and is not meant to imply any priority of considerations.

TABLE I-1 (Continued)

3. EFFECTIVE LAND USE

    3.1 Minimize incompatibility with current, projected, and potential land use.

    3.2 Maximize availability of land for public use

    3.3 Maximize availability of land for open recreational use

    3.4 Maximize multiple and shared use of ROW

    3.5 Maximize use of existing ROW

    3.6 Minimize ROW width

    3.7 Minimize conflict with resource development (e.g., mining, agriculture)

    3.8 Minimize interference with areas of cultural significance (e.g., Indian lands, historic sites, archaeological and paleontological sites)

    3.9 Minimize crossing of property; maximize use of existing boundaries

4. SYSTEM ECONOMY

    4.1 Minimize distances involved:

    total line length,
    to load centers and other distribution points,
    to essential connections (such as switches and tap-offs), and
    for access in moving men and material

    4.2 Minimize land acquisition costs

    4.3 Apply principles of engineering feasibility to minimize construction and maintenance costs

5. VISUAL COMPATIBILITY

    5.1 Maximize compatibility in visual exposure

    5.2 Minimize extent of unfavorable esthetic impact

TABLE I-1 (Continued)

6. STABILITY AND RELIABILITY OF THE LINE
    - 6.1 Minimize susceptibility to natural destructive forces
    - 6.2 Minimize maintenance problems
    - 6.3 Maximize reliability (i.e., capability of line to deliver up to planned capacity)
    - 6.4 Minimize likelihood of accidents and catastrophic failures
7. SYSTEM PLANNING
    - 7.1 Maximize capability to meet future needs (i.e., to expand line)
    - 7.2 Maximize internal system compatibility; minimize problems of intrasystem interfaces
    - 7.3 Minimize (i.e., avoid) interference with other utilities
8. WELL-BEING OF POPULATIONS
    - 8.1 Minimize displacement and relocation of residents
    - 8.2 Minimize disruption of economic enterprises
    - 8.3 Maximize (i.e., minimize diminution of) capability to provide adequate services (in terms of school capacity, road congestion, medical and protective services)

minimizing distances in a line depends largely on the pathway selected; each alternative explicitly or implicitly considered would be of significantly different length and would be associated with a distinct corridor at some distance from other routes. By contrast, a shift of a few hundred feet one way or the other within a corridor will have relatively little effect on overall length. Similarly, when it has been deemed necessary to avoid interference with some cultural monument such as a battlefield or park, the area may have to be completely curcumvented, rather than the line merely shifted to run along the boundary instead of across the park. On the other hand, interference with other utilities may sometimes be avoided by properly locating the centerline; a high-voltage electric transmission line may be incorporated in the same corridor as a pipeline if an adequate distance between the two is provided. Objectives relate both to choosing a location for a line and to the design features by which it is implemented. For example, to minimize erosion, highly erosive areas should be avoided; however, no matter where the line is located, proper protective measures are required during clearing, excavation, and other construction activities. Sometimes there is a trade-off between location and design features. While general practice has favored wide separation between overhead transmission lines and other utilities whose operation may be adversely affected, it is possible -- often only at considerable expense -- to locate them together.

Clearly, not all of the objectives can be met to the same extent, because some are inherently incompatible. Limiting distance of a line to its absolute minimum is possible only if environmental features (as well as some engineering considerations including stability of the structure and construction costs) are ignored. Maximizing multiple use of ROW by different utilities is not fully compatible with the objective of minimizing interference. Compatible land use may sometimes be attained at the expense of adverse visual impact. It is part of the skill required in impact assessment and optimum route selection to balance the different considerations and reach a decision best reflecting the inherent trade-offs.

Constraints

There are few, if any, binding constraints or absolute conditions that always exclude a utility line from a specific area. Most constraints represent conditions that are to be avoided where better alternatives are available and/or that require special situations in which the local features of the environment are so severe that a constraint becomes binding, causing the planners or evaluators of a projected line to look elsewhere. The difference between an objective involving minimization and a constraint that becomes an exclusion condition is usually a matter of degree and it is rarely possible to stipulate a general threshold at which a constraint becomes binding. For example, it is always desirable to minimize disturbance to wildlife and particularly to rare or endangered species, but some situations may involve what is deemed a vital habitat so that a binding constraint results. The point is that constraints always require careful analysis to determine whether they represent conditions that should be avoided by rerouting the line or whether the inherent problems can be successfully dealt with by mitigating measures. In some situations one constraint condition must be chosen over another as the lesser of two evils.

With the understanding that it is impossible to specify in absolute terms the conditions that define a constraint, the following list includes those that seem particularly to apply in practice, but which do not necessarily involve exclusion conditions in all situations:

a. Vital habitats of rare, threatened or endangered species.

b. Unstable terrain where the line would be endangered by slides, subsidence, etc., and floodplains where the danger of damage to the line from flooding is significant.

c. Active seismic faults and other hazardous geologic conditions. A fault may have to be crossed, particularly by an overhead transmission line, but a utility line is not likely to be laid along a fault.

d. Regions of special cultural significance, including those of very high scenic value or representing unique natural features.

e. Recreational and conservation areas such, as national parks, fisheries, and wilderness areas.

f. Areas of weather peculiarities, such as heavy icing and natural wind tunnels.

g. Terrain so steep and rugged and/or accompanied by erosive conditions that the line would be endangered or construction would represent a danger of critical erosion.

h. Highly sensitive ecosystems, such as may be found in wetlands of shrinking extent or in fragile vegetative systems in tundra or thin-soil regions.

i. Congested population areas.

j. Transportation centers, especially airports and flight lanes, or road hubs, merging points, etc., where congestion is high.

For underground lines, corrosive soils and soils with high electrical conductance offer difficulty and require special protection. They are sometimes avoided but do not necessarily preclude installation. In regard to soil conductance, the requirements for pipelines and underground electrical lines differ. Pipelines may require low thermal conductivity in the soil, whereas electrical cables benefit from high thermal conductivity. Buried pipelines tend to avoid soils with high electrical conductance, whereas it is not necessary to do so for electrical transmission.

Factors

The individual factors represent the detailed aspects of the environment and of the engineering features that must be considered in selecting a corridor or designing a line. Factors are grouped into sets and each related set is discussed in a specific Section (III-VI inclusive). Section III treats characteristics of the natural and physical environment that determine suitability of an area for locating a line and which, in turn, may be affected by the utility. It includes consideration of terrain, soils, seismography and hydrology. Section IV discusses the factors governing the impact that a utility line may have on living systems and includes terrestrial ecology and aquatic biota. Section V concerns elements of the human environment, such as land use and esthetics. Section VI addresses the technical factors.

SECTION ii
UTILITY LINE PROPOSAL EVALUATION

SECTION II

UTILITY LINE PROPOSAL EVALUATION

PURPOSE

This section presents a suggested set of steps to be followed in evaluating a utility line proposal, including the assessment of its potential environmental impact. Other methods and approaches that differ in detail can, of course, be used, but the present procedure incorporates all of the key actions and decisions necessary for evaluation of a proposed line.

As noted in the preceding section, the evaluation is focused upon the needs of the Department of the Interior in executing its responsibilities to manage its public lands in the 11 Western States. However, the material presented has sufficient generality for use in other areas of the country and by other evaluators. Details of the actual procedure used will necessarily vary from one governmental agency to another, and they are subject to periodic change even within the same office. Criteria employed by Federal, state, and local authorities differ in scope to reflect the differences in responsibility at each governmental level; however, with regard to the steps that should be taken, the data required, and the decisions that have to be made, the evaluation techniques are generally similar. The proposed utility lines may vary greatly, from a trunk pipeline designed to deliver Canadian oil across more than a thousand miles involving many acres of public lands to a transmission line linking two substations only ten miles apart, but the concepts involved and the logic that must be employed are essentially the same.

The legal authority for evaluating proposed utility lines through Federally administered lands is given in Title 43 parts 2800 et. seq. of The Code of Federal Regulations. The Act of February 15, 1901 (31 Stat. 70, 43 USC 959) authorizes the Secretary of the Department of the Interior to permit the use of rights-of-way through public lands for electrical lines. Authorization to grant ROW through public lands for pipeline purposes is vested in the Secretary of the Department of the Interior by Section 28 of the Act of February 25, 1920 (41 Stat. 449, 43 USC), as subsequently amended. The ROW "includes license, permit, or easement as the case may be."

For convenience and ease of reference, much of the material in this section is provided in checklists. These checklists are presented with some hesitancy. Experience shows that checklists, instead of functioning as an aid to facilitate an operation, can sometimes constrain the user's originality and initiative. In particular, if not used carefully, a checklist tends to become a maximum set of items that should not be overlooked. Therefore, it should be stressed that the checklists in this section are not intended to set limits on what must be done. Many utility line proposals may require consideration of details or the taking of specific steps not explicit in these checklists. On the other hand, the fact that an action or a consideration appears in a checklist is intended only to lessen the likelihood that it may be overlooked; it is meant to ensure that a decision on whether or not to include it is consciously made.

This section presents the steps necessary to evaluate a utility line proposal and indicates the general kinds of data required. Later sections of this report contain specific information necessary as background material. It is envisioned that primary use will be made of Section II, with later sections serving as reference material that may be consulted at various points in the evaluation procedure, as necessary, to provide details regarding specific considerations.

OVERVIEW

Interaction between the applicant and the government evaluation team comes about because of the applicant's legal need to secure authorization to proceed with the proposed utility line. A power company or a utility that transfers products by pipeline has a legal responsibility to provide the goods and services for which it has been granted a franchise. The granting of a ROW is, however, a discretionary action; the government must decide whether, as proposed in a specific application, authorization for a ROW should be approved. Under the National Environmental Policy Act (NEPA) of 1969, and other Federal legislation, as well as under various state statutes and regulations (see Section VII), the government is responsible for ensuring that the means of providing these services are compatible with best current uses and long-term preservation of the environment. The process of evaluation is, and should be, one of cooperation, with both parties working together to locate the utility line in the most appropriate place and to utilize construction, operation, and maintenance practices that will ensure minimum environmental disturbance.

It is important that the evaluation process begin with preliminary and informal consultation between the utility and the governmental agency that will have primary responsibility. For example, with a proposal that will involve crossing public lands, there might be initial discussion with the U.S. Forest Service or the Bureau of Land Management; a purely local action might involve conferences between the utility and a county planning board. Such early coordination enables any constraints on a possible location or other problems to be brought to light early in the planning process and can save time that might otherwise be wasted in pursuit of an unacceptable approach. Adjustments are easier at an early stage, rather than after resources have been committed. There is also the possibility that duplication of effort in the collection of data may be avoided.

Application for a utility line ROW is generally made under a system of cost recovery. That is, the government obtains funds from the applicant to cover the time and expense of the environmental analysis and other requirements of the evaluation process. Acquiring more information from the applicant after the proposal is first received delays the evaluation and requires additional effort, all of which will be reflected in the costs. Hence, a complete proposal containing all of the necessary data that can be anticipated will not only save time, but will also help to minimize the applicant's costs.

The evaluation of a utility line proposal may require from one or two weeks to more than a year, depending upon the complexity of the proposed action and the data available. The basic concept of the evaluation process is shown in the flowchart in Figure II-1. As can be seen, there are numerous actions and decisions that must be made and formal requirements that must be met, depending upon the particular agency involved with the evaluation procedure. Figure II-1 is merely representative of the logic required at a general level in the evaluation procedure and is in no sense prescriptive of the sequence of operations.

For ease in following the logic in Figure II-1, certain conventions are followed. Steps taken are indicated in rectangular boxes, whereas decisions are represented in diamond form showing separate paths followed according to whether a "yes" or "no" determination is made. The "no" line always proceeds from the bottom of the diamond, whereas the "yes" line projects a path from the side. Each distinct state (as tabulated in the checklists below) comprising a set of related actions and decisions begins a new line and is numbered sequentially from 1 to 5.

The logic of Figure II-1 is expanded in the subsections that follow.

PRE-PROPOSAL REVIEW (Line 1 of Figure II-1)

During the planning phase, the applicant and appropriate governmental agency should meet to discuss the proposed line. The aim of this early coordination is to obtain a complete project description to assist in the environmental analysis. Government actions can then be coordinated to establish the lead agency that will have responsibility for preparing an environmental assessment. Adequate manpower, funds, and time can be scheduled. Also, during such preliminary consultation with the applicant, discussion of existing and/or potential environmental constraints may obviate possible problems when the application is formally submitted.

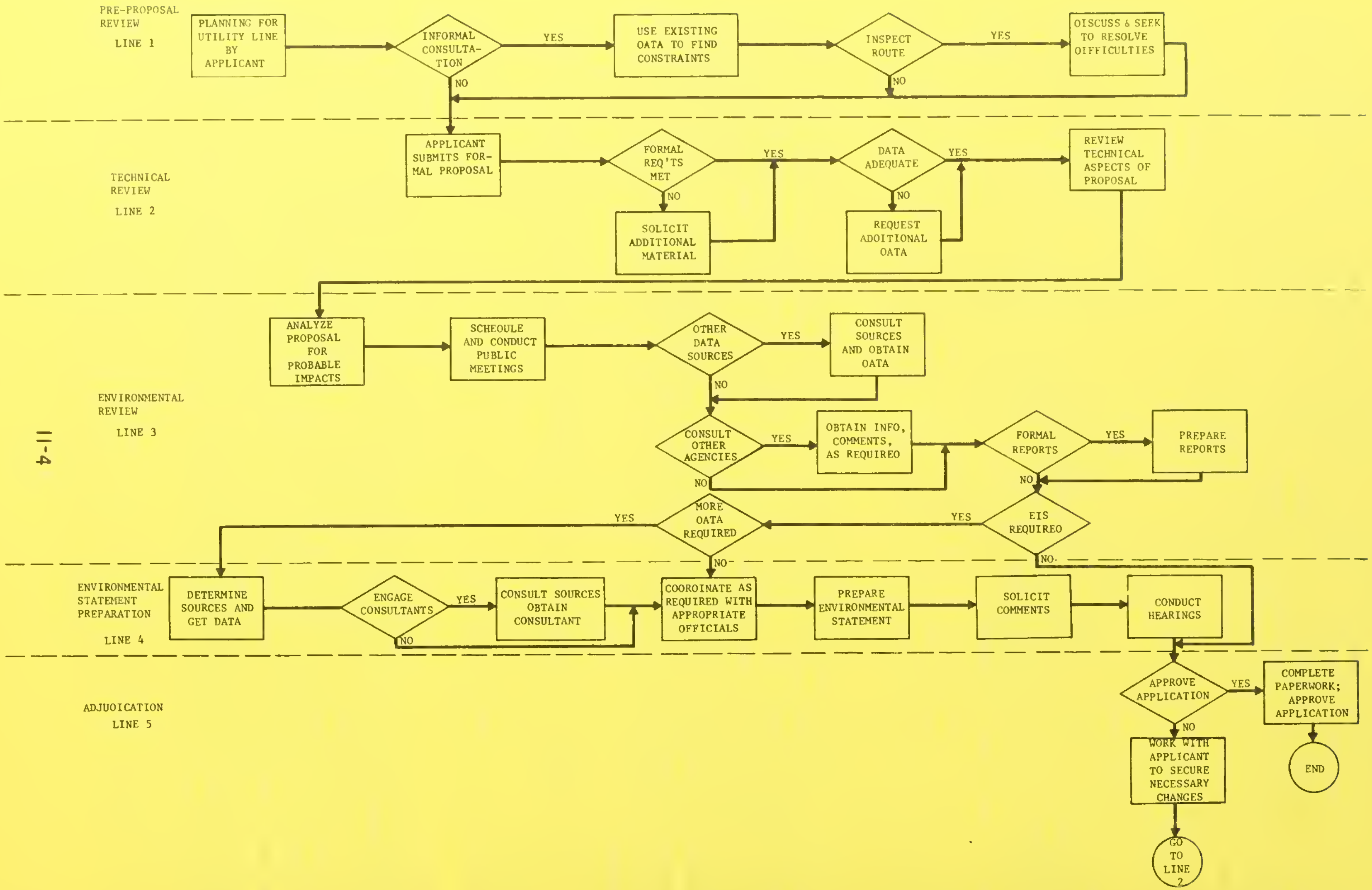

PRE-PROPOSAL REVIEW
LINE 1
PLANNING FOR UTILITY LINE BY APPLICANT
INFORMAL CONSULTATION
YES
NO
USE EXISTING DATA TO FIND CONSTRAINTS
INSPECT ROUTE
YES
NO
DISCUSS & SEEK TO RESOLVE DIFFICULTIES
TECHNICAL REVIEW
LINE 2
APPLICANT SUBMITS FORMAL PROPOSAL
FORMAL REQ'TS MET
YES
NO
SOLICIT ADDITIONAL MATERIAL
DATA ADEQUATE
YES
NO
REQUEST ADDITIONAL DATA
REVIEW TECHNICAL ASPECTS OF PROPOSAL
ENVIRONMENTAL REVIEW
LINE 3
ANALYZE PROPOSAL FOR PROBABLE IMPACTS
SCHEDULE AND CONDUCT PUBLIC MEETINGS
OTHER DATA SOURCES
YES
NO
CONSULT SOURCES AND OBTAIN DATA
CONSULT OTHER AGENCIES
YES
NO
OBTAIN INFO, COMMENTS, AS REQUIRED
FORMAL REPORTS
YES
NO
PREPARE REPORTS
EIS REQUIRED
YES
NO
MORE DATA REQUIRED
YES
NO
ENVIRONMENTAL STATEMENT PREPARATION
LINE 4
DETERMINE SOURCES AND GET DATA
ENGAGE CONSULTANTS
YES
NO
CONSULT SOURCES OBTAIN CONSULTANT
COORDINATE AS REQUIRED WITH APPROPRIATE OFFICIALS
PREPARE ENVIRONMENTAL STATEMENT
SOLICIT COMMENTS
CONDUCT HEARINGS
ADJUDICATION
LINE 5
APPROVE APPLICATION
YES
NO
COMPLETE PAPERWORK; APPROVE APPLICATION
END
WORK WITH APPLICANT TO SECURE NECESSARY CHANGES
GO TO LINE 2

FIGURE II-1
GENERAL LOGIC OF UTILITY LINE EVALUATION

As appropriate, additional actions may be involved:

a. Other government agencies may be contacted for informal coordination.

b. Governmental data files could be made available to the applicant to facilitate his planning by avoiding duplication in gathering information.

c. It may be appropriate to participate with the utility planning staff in a field inspection of the area within which the utility line is proposed. Alternative routes could also be inspected at this time.

Consultation with the Applicant

In consulting with the utility firm(s) proposing the line, a number of points should be determined, such as those listed below:

- Why is the proposed project necessary?
- How large will it be and what components are required?
- How does the proposal fit into long-range plans of the applicant?
- What potential constraints exist?
- What corridors are available for possible placement of the ROW?
- What existing ROW's have a potential for shared use?
- What is the time frame of implementation?
- What construction techniques are available?
- What specific further data are required and to how much analysis should it be subjected?

Although most of the requirements are fairly self-evident, a few words of discussion are in order.

Representatives both of utility companies and of government agencies charged with environmental assessment have stressed the need for explaining the justification for constructing the line and why it is being proposed in a specific area. The applicant has usually considered a number of possible locations and, in fairness to its own case as well as for assistance to government evaluators, should indicate what constraints were encountered elsewhere and what led to the choice of the proposed corridor. The need for the product or service to be provided is a separate determination that lies outside the process of environmental evaluation. However, a better assessment can be expected if the evaluators understand how a line in the proposed location fulfills that need, how it is to be integrated with existing facilities, and what relation it has to long-term plans for development of other facilities in the region.

A detailed knowledge of the scope, magnitude, and technical components of the proposed line are vital determinants in estimating its probable impact. In general, the concept of a corridor should be used as a basis for description, rather than as a definition of where the exact centerline will ultimately be, since such an approach allows for flexibility in actual line placement. However, some general utility line parameters are required:

- approximate ROW dimensions
- components that will be placed within the ROW
- size of the construction work force
- number and general location of access roads

ROW dimensions may vary at specific points due to local conditions and placement of specific components. A general indication of dimensions should be given by the applicant, together with any factors anticipated that may cause variation. Auxiliary components should not be overlooked, such as substations for power lines, compressor or booster stations for pipelines, and storage tanks for pipelines.

For pipelines, the following information is needed:

- pipeline size or sizes
- system capacity
- flow rate

For electric transmission lines, the following parameters are required:

- voltage
- mode or type of current (a.c. or d.c.)

- number of conductors

- number of circuits

More detailed data will ultimately be required to permit an effective technical review.

TECHNICAL REVIEW (Line 2 of Figure II-1)

After the applicant's formal proposal is received, it must be reviewed to determine whether all required procedures have been complied with and all supporting data are adequate. Data collection may continue throughout much of the evaluation process. As already noted, it should begin during informal consultation between the applicant and the governmental agency before the proposal is submitted.

This phase of the evaluation reviews the applicant's proposal to ascertain that sufficient detail on the proposed action has been furnished. If standard design parameters (such as right-of-way dimensions, voltage, pressure, grades, etc.) or engineering designs (structures, substations, span length, conductor size, pipe size) have not been proposed, a justification should be included. Construction details should be reviewed to ensure that the applicant has adequately considered the magnitude of the project, type of terrain to be traversed and problems which might be encountered. Only after the proposal has been reviewed for its adequacy of detail can the environmental assessment of its potential impacts be undertaken.

Description of the Proposed Action

The description of the proposed action should include adequate information on all the items considered in the previous subsection on consultation with the applicant and presented in the checklist of factors to be considered in the Technical Review (Table II-1).

State and Federal regulations often specify that the applicant submit, with the proposal, particular information regarding the current environment. For example, an application to use a ROW through public lands must be accompanied by a "detailed description of the environmental impact of the project" to include "among other things, information about the impact of the project on air space, air and water quality, scenic and esthetic features, historical and archaeological features, and wildlife, fish and marine life" (43 CFR 2850). Much of the environmental data should, however, be developed by the evaluation team from other sources.

Regarding probable impacts, the applicant is usually in a good position to indicate the most likely ones to be expected and the means for preventing them or minimizing their damages. Most utility companies are experienced in constructing lines with due regard for the potential problems of erosion, water quality, ecology, land use, and esthetics and in applying standard methods to avoid or mitigate potential effects. Evaluation generally benefits from an indication by the applicant of the environmental problems typically encountered with a particular kind of utility line installed under specified conditions, as well as special techniques and equipment that may have been developed for coping with these. For example, a rock chain saw that cuts stone has been successfully employed to avoid the need for blasting with attendant scars on the landscape; in some situations, its use could eliminate objections to construction through rocky terrains. Wetlands are regarded as sensitive areas to be avoided because of potential damage, but small ones can sometimes be completely spanned by transmission lines so that no significant impact results.

The applicant should include information regarding alternative means that he has considered for meeting the needs that gave rise to the proposed line. In a large-scale action, such as a long transmission line to deliver power from a new generating station to a distant load center or a major trunk pipeline spanning hundreds of miles, the applicant will often have performed a comprehensive study to select a suitable corridor within which the line will be located. If so, a number of alternative routes have probably been documented and may be described in a report accompanying the application. In minor actions, such as a spur line of a few miles, the application is likely to be specific as to a single proposed location, with little scope for alternatives.

Technical Review

Technical review of the action proposed in the application for the utility line ROW should include an in-depth assessment of all the points listed above in the subsection on Consultation with Applicant. All of the factors in the checklists in Table II-1 for general considerations, Table II-2 for transmission lines, and Table II-3 for pipelines should also be assessed. Sections VI and VIII contain background material on technical factors and on ROW sharing, respectively, for use, as appropriate, in such a review.

The time frame within which the line will be implemented is important from several points of view. It determines how long the environment will be exposed to the various impacts, when restoration can be undertaken, and what seasons of the year will be involved. Implementation of a utility line typically proceeds in phases covering preparation, installation, decommissioning, and dismantling. All of these should be considered. Other discrete operations should be identified, such as excavation, yarding of timber, cable stringing, and tower erection. The probable impact of the line ultimately must be assessed in terms of installation and operation. Typical sequences of the

TABLE II-1

CHECKLIST OF FACTORS APPLICABLE TO BOTH TRANSMISSION LINES AND TO PIPELINES TO BE ASSESSED IN TECHNICAL REVIEW OF PROPOSAL

LINE LOCATION

- Corridor (broad path within which line will be located)
- Proposed location of ROW within corridor
- Constraints on location of corridor and ROW
- Alternative locations

CONSTRUCTION TECHNIQUES

- Equipment
- Manpower
- Access
- Excavation
- Emplacement
- Crossings (water, sensitive land areas, other ROWs)
- Safety factors and protective measures
- Phasing and rate of construction
- Restoration requirements

MAINTENANCE TECHNIQUES

- Schedule
- Equipment
- Access
- Manpower
- Vegetation control
- Procedures for emergency repair and maintenance

POTENTIAL FOR ADDITIONAL ROW USES

- Shared use with other utilities
- Multiple use (for community and/or commercial purposes)

TABLE II-2

CHECKLIST OF TRANSMISSION LINE FACTORS TO BE ASSESSED IN TECHNICAL REVIEW OF PROPOSAL

FACILITY DESIGN

- End points
- Interconnections
- Voltage
- Number of circuits
- Structures - - - - - - - - - - general types
  - factors governing use of each
  - span lengths
- ROW requirements - - - - - - - widths
  - lengths of segments
  - vertical dimensions (based on sag and clearance requirements)
- Redundancy requirements- - - (i.e., any applicable consideration of system reliability necessitating a new ROW rather than upgrading an existing ROW)
- Special requirements for underground lines

POTENTIAL FOR UPGRADING LINE

- Voltage increase
- Additional circuits
- Parallel line(s)

TABLE II-3

CHECKLIST OF PIPELINE FACTORS TO BE ASSESSED IN TECHNICAL REVIEW OF PROPOSAL

FACILITY DESIGN

- End points
- Interconnections
- System capacity
- Flow rate
- Pipe size
- Operating pressure
- Auxiliary elements (tank farms, booster or compressor stations, communications and power lines)
- ROW requirements - - - - - - lengths of segments
  - widths (during construction and operating phases)
  - vertical dimensions (values, vertical positioning of above-ground pipe, clearance requirements for crossings)

SPECIAL FEATURES OF PIPELINE CONSTRUCTION

- Crossings (water, sensitive land use, industrial utilities with other ROWs)
- Constraints and problems of excavation

POTENTIAL FOR UPGRADING LINE

- Increased flow rate
- Looping

major phases and of the activities that comprise each are given in Table II-4 for transmission lines, and in Table II-5, for pipelines.

The implications of the line in terms of other components and their potential for environmental impact are sometimes overlooked. A transmission line typically involves one or more substations to tie into a grid or connect with a distribution system. If a line that crosses public lands is to deliver power from a new generating plant, the impacts of the plant itself should be considered, even though the plant is to be built on private land. There may even be important socioeconomic effects to be assessed in the delivery of some specified number of megawatts of power to a load center. The environmental analysis and impact statement regarding a proposed coal slurry pipeline might provide the only means for addressing the impacts of mining the coal and of using it at the delivery point. Sometimes, these secondary and implied effects of the proposed utility line can be brought out only by querying the applicant.

ENVIRONMENTAL REVIEW (Line 3 of Figure II-1)

During this stage of the evaluation, the applicant's proposal should be analyzed to determine the potential environmental consequences of the proposed utility line. The principal goal of this third stage is to determine whether an environmental statement is required. If a statement is deemed to be necessary, further data collection and analysis are deferred to the fourth stage. If an environmental statement is not found to be required, the evaluation should proceed directly to the determination of whether authorization should be granted. This stage may require contributory actions:

a. Informal meetings could be held to acquaint the public with the proposed action.

b. Additional data and information could be obtained to supplement internal files and data banks for the environmental assessment.

c. Consultations could be held with other organizations and individuals or the applicant to clarify points in question.

d. A formal report of the findings of the environmental assessment could be prepared.

Data Collection

Data required in the environmental review represents three general sources:

TABLE II-4

TYPICAL PHASES AND ACTIVITIES
OVERHEAD TRANSMISSION LINE

CONSTRUCTION	
Site preparation	land clearing debris disposll access and other roads grading fencing lay-down areas utility excavation
Erection of structures	excavation foundations superstructure
Installing overhead wires	towers stringing debris disposal
OPERATION	
Electrical transmission	routine inspection
Maintenance	ROW (tree pruning, herbicide application) line (insulator cleaning, line repairs
DECOMMISSIONING	
Dismantling	disconnect utilities equipment dismantling equipment removal structure demolition
Site restoration	remove paved surfaces debris disposal grading revegetation

TABLE II-5

TYPICAL PHASES AND ACTIVITIES
PIPELINE

CONSTRUCTION	
Site preparation	land clearing
	debris disposal
	grading
	access and other roads
	bridging
	fencing
	lay-down areas
	utility installation
Erection of structures	excavation
	foundations
	superstructure
Pipeline construction	trenching
	crossing water
	pipe preparation
	pipe laying
	backfilling
	cleanup
	grading
	revegetation
OPERATION	
Product storage	
Product preparation	regasification, slurrying
Pumping	
Communications	
Maintenance	routine inspection
	ROW (herbicide application)
	line repairs
DECOMMISSIONING	
Dismantling	disconnect utilities
	equipment dismantling
	equipment removal
	structure demolition
Site restoration	remove paved surfaces
	debris disposal
	grading
	revegetation

a. utility-furnished data

b. documented data (from government files, publications, and open literature)

c. data obtained from special surveys and consultants

Utility-Furnished Data

In addition to the description of the proposed action, the applicant is expected to furnish information in the following categories:

- information regarding the current environment
- potential impacts on the environment and mitigating measures
- alternatives considered

Documented Data

The information required for analyzing the environmental effects of the proposed utility line should come from a variety of sources, both within and outside of the government. Often, existing data or data developed for the specific analysis can be shared among the various agencies involved to avoid costly duplication of effort.

In addition to periodic government and technical publications, a checklist of some of the more likely data sources is provided in Table II-6. The listing cannot be exhaustive and evaluation teams should expect to develop other sources as required for particular situations.

Special Surveys

In evaluating very small utility line proposals, it may be possible to obtain all of the necessary information from the applicant, from expertise of the evaluation team obtained by past work in the general geographic area, and from documented sources. In evaluating most utility line proposals, it is likely that at some point it will be necessary to consider the need for more detailed site-specific data than can be obtained by these means. In some situations, extensive or intensive field investigation to gather data may be required. For example, the presence or absence of suspected endangered species, whose habitat is considered vulnerable to the proposed line, might be determinable only by observation over an extended period of time. There might be a specific location of a proposed line where there is controversy as to how much impact on turbidity and other aspects of water quality is likely to result from increased runoff from clearing

TABLE II-6

PARTIAL CHECKLIST OF COMMON SOURCES OF DOCUMENTED DATA FOR ENVIRONMENTAL INFORMATION

- In-house information files or data banks

  Material developed by the lead agency or participating agency.

  > Planning data developed by the Bureau of Land Management (BLM), including particularly the Unit Resource Analysis data bank compiled for each planning unit of a BLM district. This file provides an inventory of resource values, including a base map display; an assessment of the planning unit's basic physical characteristics and of current conditions in regard to lands, minerals, forest products, range, watersheds, wildlife, and recreation; an "ecological profile" displaying ecosystem quality; evaluation of "Critical Environmental Areas" and "Significant Resource Areas" as specified by state and Federal Regulations; and a socioeconomic profile (Bureau of Land Management, 1975).

- Past environmental analyses for all or parts of a region involved in a utility line proposal.

- Regional maps developed by a government agency responsible for some environmental feature. Examples: Soil, hydrology, geology, land use.

- Environmental records maintained by specific governmental agencies. Examples: Environmental Protection Agency data on air and water quality, U.S. Army Corps of Engineers and U.S. Geological Survey data on streamflow.

- State and local data maintained for regulatory purposes. Examples: Highway Department statistics, records of state game and conservation commissions, city and county tax records, and records of real estate transactions.

- Local zoning board information on land use.

and excavation. Specific field data might have to be obtained as to the slope at points within the line section and soil analysis might be required to support calculations of erosion potential; also, sampling and testing of present water quality might be indicated to establish a baseline.

Field surveys are expensive in time and manpower and require justification in terms of expected results that cannot be obtained from available data sources. Criteria useful for determining the need for such investigations include:

- doubt or controversy as to the probable effects of the line at a specific point or points
- reasonable concern that serious impacts may be among the consequences of the line
- absence of site-specific data and uncertainty that the local conditions at the site are sufficiently similar to those for which adequate documented information is available
- ability to formulate precisely the question to be resolved and to determine clearly what the survey data will be expected to show

Environmental Analysis

The environmental analysis involves the following actions and decisions:

- description of the current environment
- assessment of potential impacts of the line and mitigating measures
- decision as to whether an EIS is required

These steps are not always taken in the order shown. In particular, the decision that an EIS is required may be made very early and environmental analysis is undertaken to support development of the statement.

Description of Current Environment

The current environment is described in order to define the principal characteristics of the region that are most likely to be affected by the utility line as proposed. In practice, two criteria are particularly important in deciding how much detail should be given to each factor of the current environment:

- Importance of the factor in the particular region
- Potential susceptibility of the factor to change by the proposed utility line

Those factors most likely to require particular attention in describing the current environment are listed below:

- Factors that influence erosion potential (chiefly topography, soils, and geology) (see Section III)
- Vegetation and other land cover (see Section IV), especially relatively fragile areas such as tundra regions and wetlands
- Wildlife, including terrestrial animals, birds, fish, and other aquatic biota (see Section IV), especially mating and breeding areas and the presence of any rare, threatened, or endangered species
- Ecosystem, especially any sensitive areas where the balance might be disturbed (see Section IV)
- Land use, including present practices, historical and cultural monuments, and areas of archaeologic significance (see Section V)

Other factors will, however, need to be addressed in describing the current environment. A more complete set is given in Table II-7.

Very few, if any, utility line proposals are likely to require collection of detailed data on all aspects of the current environment discussed in Sections III - V of this report. For example, potential earthquakes or other geologic hazards represent significant consideration in few regions; when they do, the potential may be analyzed along the lines discussed in Section III. For long lines, particularly in regions of varied topography, it may be necessary to consider terrain features in more detail than for short lines or lines in unchanging flat terrain.

Section IV includes a summary of the principal wildlife and vegetative types found in the biotic provinces of the West. Although it is not likely that detailed statistics on distribution of fauna and flora will be required, procedures for obtaining these data when necessary are summarized in Section IV. Of particular concern are those species of wildlife officially classified by the Department of the Interior as rare, threatened, or endangered. Section IV gives a comprehensive listing of such species found in the 11 westernmost states. The factors of particular significance in types of land cover are discussed in that section according to several classifications.

Particularly sensitive types of land cover, such as tundras, wetlands, and areas irrigated by a sprinkler system are particularly likely to require development of specific and detailed information.

One possible system of land use categorization is given in Section V along with background information on other human factors such as esthetics, noise, and radio/TV interference.

Impact Assessment

The most important phase of environmental review is estimation of the impacts that the proposed utility line is expected to have. Potential impacts should be specifically presented in terms of the following:

- WHAT the impact will be
- HOW and WHY it will occur
- WHEN it will occur
- WHERE it will occur (often may be shown by map)
- QUANTITATIVE expression of how great it will be (if possible)
- SIGNIFICANCE in terms of what it means for the region, considering the extent to which the same factor or comparable factors exist

The interrelationship of various factors should be analyzed, and the chain of cause-and-effect should be traced to its logical conclusion.

Table II-7 presents a checklist of environmental factors to be considered as to their potential impacts from transmission lines and pipelines. Further details are presented in Sections III, IV, and V of this report. Although the set of environmental factors in Table II-7 is fairly comprehensive, the listing of possible impacts is by no means exhaustive; they are merely representative of those frequently encountered. Hence, they comprise a minimum list for consideration. Many other impacts are possible under particular conditions and should be examined for how likely they are in the specific environment analyzed. On the other hand, it should be stressed that the checklist in Table II-7 does not imply that all of the impacts (or any particular set of those listed) are to be expected for any proposed utility line.

TABLE II-7

CHECKLIST OF ENVIRONMENTAL AREAS SUBJECT TO POTENTIAL IMPACT

ENVIRONMENTAL AREA	FACTORS	TYPES OF IMPACT
Physical (Section III)	Topography Soils Edaphic effects	Erosion (from water and wind); subsidence, landslides as a result of removing vegetation during clearing for line or access roads, excavation and/or trenching for burial of pipe or underground transmission cables or for clearance of overhead lines.
	Mineral resources	Interference with present or future exploitation.
	Availability of water (Water quantity)	Loss of available groundwater through clogging of soils in aquifer-recharge area by sediment-laden runoff during construction; diversion of streams, interference with runoff patterns during clearing, excavation, trenching; clogging of streams, reservoirs, water storage areas; dewatering for trenching.
	Water quality	Degradation through increased turbidity from erosion during runoff; resuspension of bottom sediments during trenching or scouring due to structures in a stream; pollution of groundwater and surface waters from use of pesticides and herbicides in ROW maintenance and/or runoff from construction wastes.
	Air quality	Fugitive dust from moving vehicles (chiefly during construction); emissions from construction equipment and vehicles.

TABLE II-7 (continued)

ENVIRONMENTAL AREA	FACTORS	TYPES OF IMPACT
Biological (Section IV)	Land cover Vegetation	Loss of vegetative cover from clearing, excavation, or trenching; damage to vegetation resulting from erosion of cleared areas or from herbicides used to maintain ROW; damage to standing timber during removal operations.
		Secondary effects such as soil compaction and soil mixing which reduce fertility.
		Accidental damage to sensitive types of land cover such as tundra or wetlands.
		Interference with sprinkler systems on irrigated lands.
		Invasion of weed species on cleared areas.
	Fauna (terrestrial and aquatic)	Loss of breeding, nesting, forage areas, other habitat.
		Destruction of aquatic life from degradation of water quality.
		Disturbance of rare, threatened and endangered species; electrocution of raptors from unsuitable poles for distribution lines serving pipelines.
		Benefit to some terrestrial wildlife species through clearing that provides "edge space" for nesting, lower vegetation for food.
	Ecologic Relationships	Interference with ecologic balance, from effects on soils, vegetation, wildlife, especially in fragile

TABLE II-7 (continued)

ENVIRONMENTAL AREA	FACTORS	TYPES OF IMPACT
		areas; dimunition or destruction of species occupying critical role in the food chain or nutrient cycling; inadvertent introduction and/or accelerated spread of pest species from interference with ecologic balance and creation of cleared path for rapid growth and migration.
Human Environment (Land Use, Esthetics, etc.) (Section V)	Land use Land values	Removal of small amounts of land from other usage; possible interference with adjacent activities; incompatibility of line (especially overhead transmission lines) with adjacent activities possibly reducing land values in the short run; effect of the line on land use and development patterns in undeveloped regions.
	Esthetics	Visual incompatibility of visible elements of line (especially in scenic areas); adverse impact on viewers in terms of large numbers of visual contacts.
	Noise Radio/TV interference	Noise from construction operations and equipment; noise at short distances from auxiliary operating equipment (e.g., pumping and compressor stations); audible noise and radio/TV interference at short distances due to corona effect of transmission lines (especially in remote areas during foggy and rainy weather).
	Community Impact	Possible pressure on community services and facilities from large projects requiring construction force concentrated in one region; possible secondary impacts from change in land use or land value patterns.

Need for EIS

Individual Federal agencies have their own criteria for determining the conditions under which an EIS is required by NEPA. State authorities are also guided by the individual requirements of the environmental laws and regulations under which they operate. NEPA specifies the following criteria (analogous criteria exist under most state environmental laws):

- "major" action
- "significant" effect
- affecting the "quality" of the human environment

In determining whether an EIS is required under the policies of a particular agency, the checklist of questions below may provide useful guidance. The list is based on a survey of Federal agency guidelines as published in the Federal Register.

- Is the scale of the proposed facility and/or its geographical extent large by absolute standards or by comparison with routine requests received for ROW? (For example, a line hundreds of miles long is large in the absolute sense. When most requests involve only short distribution power lines, a high-voltage transmission line to connect an existing grid with a new generating plant might well be large on a relative basis.)
- Does the proposal involve an action specified by agency regulations as likely to require an EIS? (For example, regulations of some agencies stipulate that electric transmission facilities involve actions affecting the quality of the human environment and, hence, are appropriate for an EIS.)
- Will there be effects in any of the environmental areas specified by agency policy? (For example, some agencies specify concern for particular environmental factors, such as air and water quality, wetlands, wilderness areas, and scenic attractions.)
- Will the effects be quantitatively significant in terms of the uniqueness of the environmental factor affected, the relative magnitude within the area of the resource affected, and/or its impact on the human population? (For example, the significance of clearing through the only large wooded area within a region might be much

greater than clearing in a heavily timbered region; stream turbidity decreasing the fish population during and immediately after construction might be much more significant if it involved a stream highly valued for sports fishing rather than one attracting relatively little fishing.)

- Is the action in the proposal one that has aroused or is likely to arouse public controversy? (The degree of opposition is some indication of how the quality of the human environment is affected, at least as viewed by those who feel they are affected.)

- Will the cumulative effect of the proposed action together with previous similar ones, or in conjunction with others that may be expected to follow, be significant? (For example, a single line through an undeveloped recreational area might have an impact judged insignificant, but if it became a precedent or opened the way for further utility lines, the impact could be deemed significant; the cumulative effect of additions that result in widening the ROW across agricultural land might seriously affect farming practice, where the original ROW had not.)

- Will the secondary and associated impacts be significant? (For example, a transmission line across public land may in itself have only minor consequences, whereas the generating plant it is to serve and the coal that must be mined as fuel have significant impacts. The secondary impacts on life style of what is fundamentally a tourist and recreational area as a result of a transmission line that delivers large additions of electric power might be significant.)

Use of the questions in the above checklist does not mechanically solve the problem of whether to produce an EIS. It is not necessarily true that if the answer to any question is "Yes," an EIS is required. A proposal might involve one of the actions specified in the agency guidelines as likely to require an EIS or possibly affect one of the agency's critical environmental areas; however, if there were clearly only trivial impacts, an EIS might not be needed. The checklist should be useful in ensuring that the most important considerations are not overlooked. "Yes" answers to two or more of the questions would certainly provide a strong indication that an EIS should be prepared.

Use of Consultants

Where the lead agency has a relatively large staff, there is likely to be considerable expertise in regard to both particular environmental areas and to the locality of the proposed line. If additional expert assistance is required, it may sometimes be available from other governmental agencies. For example, the Environmental Protection Agency represents a source of expertise in regard to possible effects on air and water quality where these questions may arise, as does the Fish and Wildlife Service regarding possible biotic impacts. State departments and local boards and commissions may also be able to provide expert assistance. The experience of Federal agencies with specific responsibilities in regard to power and energy, such as the Bonneville Power Administration, Tennessee Valley Authority, and the Federal Power Commission, would be useful for estimating possible impacts. Except where the agencies are participating in the evaluation, they may not be able to devote the effort needed at the time to provide definitive answers to specific questions. They may find it more appropriate to comment later on the EIS.

In some situations, it may be economically beneficial to engage outside consultants to study an unusual problem. Possible study examples include: the stability of a particular type of soil under a specified set of construction conditions; available excavation techniques to locate a pipeline or emplace transmission towers with minimum adverse impact in a given type of terrain; and effects of a controversial river crossing.

Experience in similar types of analysis provides a useful guide to selecting an appropriate firm. This information can usually be obtained from contracting officers within the same or an associated government agency that has had experience with such contracts, or from a regional service center (one example is the Denver Service Center, supporting the Bureau of Land Management, Department of the Interior). One situation where such outside expertise is normally required is in the evaluation of a specific locality to determine what features of archaeological interest it contains.

Criteria for determining whether to engage consultants include:

- availability of required data and expertise from other sources

- staff capability to perform the necessary analysis

- time required for the staff to collect the data and perform the analysis

- contractor schedule for delivery of results

- cost of contractor services

Public Meetings and Coordination

After the application has been received, it is a common practice to schedule meetings in localities affected by the proposed line. The purpose of these meetings includes:

- acquainting interested citizens with what is planned

- identifying potential problems in time for resolution

- developing alternatives that require consideration

If there is sufficient interest, follow-up meetings may be arranged to keep interested groups and individuals informed. The degree of public interest can provide useful guidance as to the probable impact of a proposed line with regard to land use, esthetics, and other human factors. Some established procedures for evaluation of utility lines (such as the Environmental Analysis Record of the Bureau of Land Management) require that intensity of public interest be explicitly reported.

Coordination takes place throughout the evaluation process. Participating governmental agencies contribute designated input to the environmental assessment in advance for such joint preparation of the analysis. Other agencies may also be solicited to contribute facts and/or expert assistance during the course of the study. Such sources may represent agencies of the Federal government, commissions and departments at the state level, and planning boards and other local authorities.

Applications containing utility line proposals are not generally circulated. However, they are public information in the broad sense and are available to interested parties on request.

PREPARATION OF AN ENVIRONMENTAL STATEMENT (Line 4 of Figure II-1)

If an Environmental Statement is found to be required, an independent and more comprehensive environmental analysis is performed (drawing upon the environmental assessment) and its results are documented. The following actions are required to perform this effort:

a. An environmental statement team or task force is formed.

b. Additional data, as required, are collected.

c. Consultants are engaged, if required, to perform special studies and surveys that cannot be conducted by the evaluation team (e.g., an archaeological survey or special environmental baseline inventory).

d. The required analysis is conducted and the draft environmental statement is prepared and furnished to the public and other agencies for comment. Public hearings could be held to solicit some of these inputs.

e. Comments are addressed and a Final Environmental Statement is prepared.

An Environmental Statement is circulated in draft form for comment to Federal, state, and local authorities and to citizen and special interest groups identified as having a particular concern in the proposed action. Who receives a draft EIS for comment depends on the particular application. In general, the government agencies generally addressed include those having established environmental or land management responsibilities. A minimum checklist of possible agencies and interest groups that should be expressly considered is given in Table II-8. The list is neither complete nor prescriptive, i.e., often an EIS should be sent for comment to sources not on the checklist; on the other hand, it is not always in order to address every potential source listed. Private individuals and non-government interest groups from which comments are appropriate vary widely from one situation to another. Reliance should be on records maintained by the authority preparing the EIS as to who has expressed an interest in this and similar actions and as to what environmental groups are active in the locality.

Formal hearings are generally held after the draft EIS is issued. At these sessions, a transcript of testimony is taken and the proceedings become a matter of official record.

ADJUDICATION (Line 5 of Figure II-1)

In this stage of the evaluation, determination should be made whether to issue the final authorization, including all necessary paperwork. If unacceptable in its present form, the proposal should be returned to the applicant to secure the necessary changes and an iteration of the review process should be performed. The extent to which the review of the revised proposal must be conducted should be determined on a case-by-case basis.

Modification of Proposal

It sometimes happens that the proposal for the utility line has to be modified. This need may result from adjudication, if the

TABLE II-8

MINIMUM CHECKLIST OF GOVERNMENT AUTHORITIES AND PRIVATE GROUPS TO CONSIDER AS TO WHETHER COMMENTS SHOULD BE SOLICITED

(See also Council of Environmental Quality, Guidelines for Preparation of Environmental Impact Statements, August 1973, for details on responsibilities of specific Federal agencies)

Federal Authorities

Advisory Council on Historic Preservation

Agriculture Department, U.S. Forest Service, Soil Conservation Service

Council on Environmental Quality (for major actions)

Defense Department:

U.S. Army Corps of Engineers (especially where navigable waterways are involved)

Environmental Protection Agency

Federal Communications Commission

Federal Power Commission (for pipelines and major transmission lines)

Health, Education and Welfare Department (for major actions)

Interior Department:

Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
Fish and Wildlife Service
National Park Service

Transportation Department:

Coast Guard (especially where bays, harbors, or inlets are in any way involved)
Federal Aviation Administration
Federal Highway Administration - Bureau of Public Roads (where line crosses or runs adjacent to Federal highways)

State Boards, Commissions, Departments and Other Authorities Responsible for:

- Air quality
- Archeology
- Archives and History
- Board of Health
- Coastal Zones
- Conservation
- Environment

TABLE II-8 (Concluded)

- Fish, Game and Wildlife
- Forestry and Agriculture
- Geology
- Highways
- Lands
- Recreation, Parks, etc.
- Regulation of Utilities
- Rivers and Other Waterways
- Siting of Power Plants and Utility Lines
- Water Quality

Interstate, Intergovernmental, and Regional Commissions and Councils Local Board Councils, Commissions, and other Authorities:

- Boards of Architectural Review
- City Council
- Conservation and Development Commission(s)
- County Board of Supervisors
- County Road Department(s)
- Fire Department(s)
- Flood Control Districts
- Planning Commission(s)
- Sanitation District(s)
- Zoning Board(s)

Non-Governmental:

- Applicant and Any Associated Utilities
- Audubon Society (Local Chapters)
- Civic Associations
- Environmental Leagues (Local)
- Granges, Other Farmers' Organizations
- Izaak Walton League (Local Chapters)
- Sierra Club (Local Chapters)

reviewing agency, exercising its discretionary authority, finds that the proposal as submitted is not acceptable. It is also possible that the applicant could withdraw the proposal where strong opposition or other difficulties develop. In either event, the applicant has the option of modifying the proposal for the utility line and resubmitting it as a new application. The entire process of review would then be repeated.

However, modification may occur at other times during the review process. It may come about through informal consultation with the applicant, or the need for additional information from the applicant may bring to light unforeseen difficulties and cause the proposal to be modified to eliminate these. Modifications during the course of environmental review are evaluated as submitted. The potential impacts of those features of the line that have been revised are then assessed. Reassessment of environmental features previously considered is likely. For example, the modification might propose a new location for part of the line. All environmental factors affected by the line must then be assessed for the new region. If the modification relates to design features or to proposed construction techniques, the effect of these must be assessed for all of the environmental factors previously analyzed. It is possible that a number of modifications could be made sequentially, requiring several iterations of parts of the review process.

Stipulations in ROW Grant

When approval is granted for a utility line ROW, stipulations are often attached. These relate to the conditions under which the ROW is authorized. Depending on the regulations and policy governing the agency having discretionary authority for granting a ROW, there may be standard conditions that are stipulated. As one example, the Wyoming State Office of the Bureau of Land Management regularly stipulates a set of conditions under which the applicant agrees to accept a ROW grant for a transmission line. These conditions relate to rights of the Department of the Interior to utilize surplus capacity of the line. Other general stipulations frequently attached relate to restoration of the ROW construction and to maintenance procedures.

Mitigating measures to be undertaken by the applicant are often specified as stipulations to the ROW grant. Mitigating measures may cover a wide range of choices. In regard to location, a line within a general corridor may be placed to avoid areas most prone to erosion, particularly if there is danger of derogating water quality (Section III); to skirt wetlands, other ecologically sensitive areas, and critical habitats of wildlife or aquatic biota, such as those of rare or endangered species (Section IV); to bypass historic, cultural, and archaeological areas or to avoid impingement on scenic locations

(Section V); to avoid interference with other activities in urban, institutionalized, residential, or commercial areas or in rural areas where specialized techniques such as pivot-sprinkler irrigation are practiced (Section V); and to minimize disturbance to persons from noise and/or radio-TV interference (Section V).

Particular construction techniques may also be employed to reduce or prevent undesired consequences. Thus, wetlands or sensitive streams requiring protection of water quality may not need to be avoided altogether if they can be spanned by a line through selection of appropriate structures. Sensitive tundra may sometimes be safely crossed by pipelines when techniques for careful replacement of excavated material are employed. Water bars to prevent runoff and other control measures can prevent significant erosion when clearing and excavation in erosion-prone areas are unavoidable. The visual impact made by a utility line is highly dependent on the measures used to screen and blend with natural surroundings, as discussed in Section V. Most types of land use can be successfully combined with adjacent utility lines through employment of special measures, as discussed in Section V and VIII.

Sometimes, proper timing is important. In some situations, interference with wildlife may be avoided altogether if construction does not coincide with periods of special vulnerability, such as mating and breeding seasons. In some sections of the country, work in erosion-prone areas may be timed to avoid periods of heavy rainfall and runoff. Suitable techniques for revegetation and other forms of site restoration and maintenance practices may be stipulated with regard to seasonal requirements and local conditions.

A checklist of some frequently imposed mitigating measures and stipulations is provided in Table II-9.

TABLE II-9

CHECKLIST OF FREQUENTLY INDICATED MITIGATING MEASURES AND STIPULATIONS

Erosion, Soil, Other Surface Effects

- Restrictions on slope of grade on which cut-and-fill slopes may be constructed (e.g., 3:1 or less)
- Construction of water breaks or water bars on all disturbed slopes
- Designation of intervals for water breaks as a function of slope
- Designation of closer spacing than usual for water bars on unstable soils
- Prevention of vehicular traffic on steep slopes
- Provision of water bars on access roads
- Provision of adequate drainage on access roads
- Use of existing roads and trails to minimize number of new access roads
- Provision for windrowing
- Replacement of topsoil
- Restrictions on construction activity when soil moisture is high
- Removal of waste caused by applicant's activities
- Staking edge of ROW to ensure no activity of line extends beyond limits of ROW width
- For pipelines and other buried structures, compaction of soil so as to leave only a small mound

TABLE II-9 (Continued)

Vegetative Cover

Prohibition against clear-cutting or blading (in transmission lines)

Restrictions on trees to be cut

Revegetation according to specified instructions (e.g., designated mix of grass seeding or reference to state or Federal agricultural specifications, in terms of prior vegetation, stated time and method of planting, etc.)

Restrictions on debris burning

Responsibility for fire prevention and suppression, including liability for suppression costs in event of negligence as cause of fire

Use of special poles to prevent electrocution of raptors (rarely applicable to transmission lines, but may apply to distribution lines serving pipeline auxiliary equipment)

Responsibility for weed control measures

Land Use and Compatibility with Current Activities

Range improvements (such as fencing and reservoirs) within the ROW to be restored to original condition

Protection of and/or replacement of fences, where necessary to cut, as by proper bracing

Establishment of gates and cattle guards as necessary where fences are disturbed

Provision of payment for merchantable timber cut

Coordination with FAA in vicinity of airports, landing fields, or aircraft take-off and landing paths

Wildlife and Other Biotic Considerations

Assurance of unrestricted movement for fish and/or wildlife

Designation of key areas (e.g., elk calving areas) as closed to construction activities during specified periods of times

TABLE II-9 (Concluded)

Restrictions on use of pesticides (may be in terms of state, Federal, and local regulations or may be more specific)

Esthetic and Cultural Considerations

Requirements for painting or treatment of aboveground structures (e.g., painting structures a sage-green color to blend with environment; use of non-specular finish on conductors to reduce visual impact)

Designation of specific shape and type of pole or transmission tower

Screening with shrubbery and provision of other landscaping

Reporting of any archaeological or historical artifacts

Certification, survey, and salvage of any other antiquity values on land involved

Preservation of historical or cultural markers on ROW or adjacent land

SECTION III
NATURAL PHYSICAL FACTORS

SECTION III

NATURAL PHYSICAL FACTORS

OVERVIEW

This section deals with physical features of the environment that determine suitability of a specific location for a utility line or corridor and also the degree to which the line is likely to affect the natural surroundings.

Utility lines tend to have only a few direct primary effects on the physical environment. Most of the objectives that interrelate with physical factors are significant in terms of the indirect impact that will be felt by ecological systems or other users of the natural features that are directly affected. Such objectives include minimizing:

- erosion
- degradation of air quality
- interference with local hydrology
- disturbance of unique natural features
- interference with extractive industries

All of the objectives listed are closely interrelated with physical factors; but when they are not fully met, the effect is felt in terms of water and air quality, aquatic environment, land conservation, and social values.

From the standpoint of the utility line itself, natural physical factors are significant largely in terms of hazards to the line and the economics of the system. The most prevalent interaction between system objectives is with maximizing system reliability and minimizing cost. Reliability is influenced by many natural phenomena, including landslides, subsidence, lightning, flooding, and more rarely by earthquakes and volcanism, and by those factors that influence corrosion and erosion potential. Avoiding the consequences of these dangers as well as areas prone to them can increase the expense of constructing and operating the system. Measures to mitigate the impact of a utility line on physical factors and their secondary effect on elements of the environment also result in higher system costs.

Some of the problems posed by natural physical factors can be resolved by economic considerations. Avoidance of stream crossings often involves a longer route; it may be possible to cross the streams quite satisfactorily from an environmental standpoint, but the higher costs should be weighted against the greater expense of lengthening the line. On the other hand, many difficulties cannot be resolved either on strictly engineering, economic or environmental grounds, but result in trade-offs that must be determined judgmentally and in relative terms. Nearly all line construction involves some erosion so that it is not possible to avoid erosion completely; it is only possible to reduce the amount and to mitigate the adverse consequences. Furthermore, avoiding areas that are prone to erosion (such as those with steep slopes or unsuitable soil) can involve not only higher cost, but also the possibility of other adverse environmental effects (such as disturbing surface waters). Few binding constraints or absolute prohibitions emerge from considering the natural physical factors. Rather, it is a question of careful planning and implementation to avoid either adverse environmental impacts or undue difficulty in constructing and maintaining a line when it is necessary to route through an area characterized by any of the following:

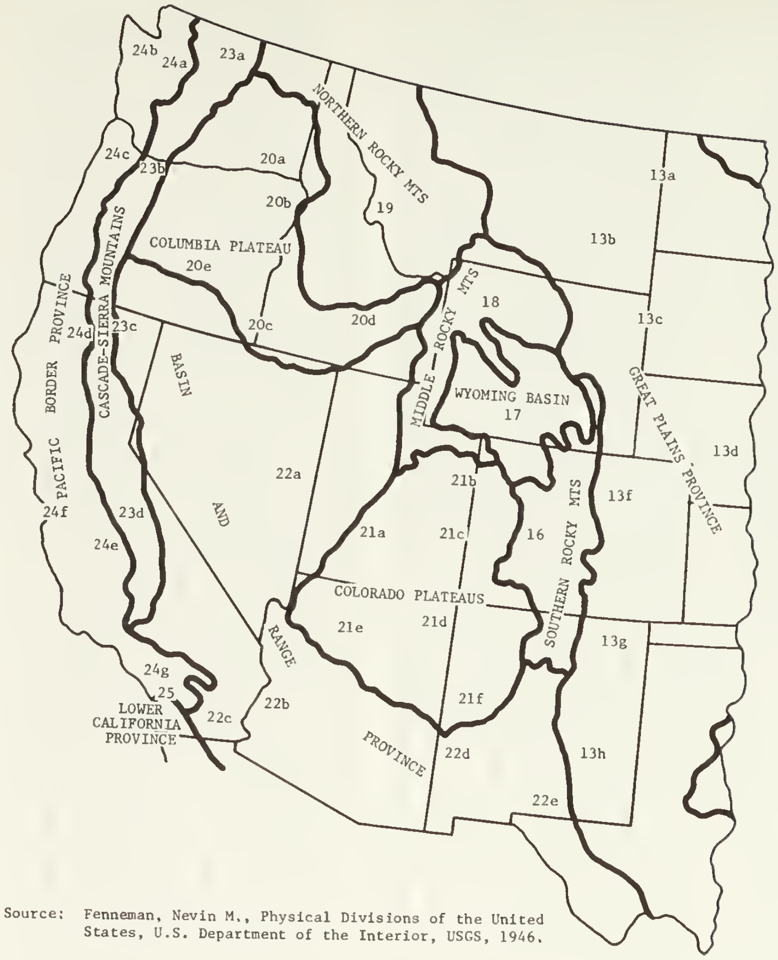
- unstable terrain
- active faults or other seismic hazards
- subsidence and other hazardous geologic conditions
- unique natural features (e.g., phenomena of special geologic or other scientific interests)
- high electrical conductivity (especially for pipelines and other buried structures).

TOPOGRAPHY

Physiographic Provinces

Land forms and topography of an area vary considerably across the country. Although modern construction methods can cope with almost any type of terrain, a utility corridor through rugged areas is generally much more expensive and has the potential to cause more adverse impacts on the surrounding environment than a route through flatlands. As a preliminary consideration, it is useful to categorize the physiographic provinces to be crossed.

There are several classifications presently in use for physiographic provinces. All attempt to group areas in terms of common terrain conditions, geology, climate, soils, vegetation, land use and other characteristics. A system proposed by Fenneman (1931) (see Figure III-1) divides the continental United States into 8 systems and 25 regions or provinces. In recognition of the significant difference that can occur within a province, a further division into more homogeneous sections is provided. The general characteristics of the provinces and sectors within a study area indicate the broad range of conditions that a utility line can be expected to encounter. For instance, the Southern Cascade Section of the Sierra Cascades Province in Oregon and Northern California is underlain by relatively young volcanic rocks. Soils are shallow, requiring more blasting than in most other areas. Although perlite and pumice occur, the section is relatively lacking in the more highly valued mineral resources (by constrast, for example, with oil-producing regions or areas where high-grade metallic ores exist). Many



Major Division	Province	Section	[illegible]
[illegible]	13 [illegible]	a [illegible]	13a [illegible] isolated mountains
		b [illegible] unglaciated	13b [illegible] terraces, local badlands
		c [illegible]	13c [illegible] domed mountains
		d [illegible]	13d [illegible] of intervalley remnants [illegible]
		e [illegible]	13e [illegible] plain
		f [illegible]	13f [illegible] peneplain surmounted by dissected lava-capped plateaus and buttes
		g [illegible]	13g [illegible]
Rocky Mountain System	16 Southern Rocky Mountains	--------	16 Complex mountains of various types, intermont basins
	17 Wyoming Basin	--------	17 Elevated plains in various states of [illegible], isolated low mountains
	18 Middle Rocky Mountains		18 Complex mountains, mainly anticlinal ranges, intermont basins
	19 Northern Rocky Mountains		19 [illegible] dissected mountain uplands, not anticlinal ranges, intermont basins
Intermontane Plateaus	20 Columbia Plateau	a Walla Walla Plateau	20a Rolling plateau with young incised valleys
		b Blue Mountain section	20b Complex mountains and dissected volcanic plateaus
		c Payette section	20c [illegible] plateaus of prevailingly weak rocks, [illegible] alluvial terraces (applies to [illegible] part [illegible])
		d Snake River Plain	20d Young lava plateau
		e Harney section	20e Young lava plateau [illegible] of [illegible] drainage
	21 Colorado Plateaus	a High Plateaus of Utah	21a High block plateaus in part lava-capped, terraced plateaus on south side
		b Uinta Basin	21b Dissected plateau, strong relief
		c Canyon Lands	21c [illegible] to mature [illegible] plateaus, high relief
		d Navajo section	21d Young plateaus, smaller relief than 21c into which it grades
		e Grand Canyon section	21e High block plateaus [illegible] Grand Canyon
		f Datil section	21f [illegible] remnants, volcanic necks
	22 Basin and Range province	a Great Basin	22a Isolated ranges (largely dissected block mountains) separated by aggraded desert plains
		b Sonoran Desert	22b Widely separated short ranges in desert plains
		c Salton Trough	22c Desert alluvial slopes and delta plain [illegible] Gulf of California
		d [illegible]	22d Isolated ranges (largely dissected block mountains) separated by aggraded desert plains
		e Sacramento section	22e Large block mountains of gently tilted strata, block plateaus, bolsons
Pacific Mountain System	23 Cascade-Sierra Mountains	a Northern Cascade Mountains	23a Sharp alpine summits of accordant height, higher volcanic cones
		b Middle Cascade Mountains	23b Generally accordant summits, higher volcanic cones
		c Southern Cascade Mountains	23c Volcanic mountains variously eroded, very distinct range
		d. Sierra Nevada	23d Block mountain range tilted west, accordant crests, alpine peaks near east side
	24 Pacific Border province	a Puget Trough	24a Lowlands of diverse character, in part submerged
		b Olympic Mountains	24b Generally accordant crests, local alpine peaks
		c Oregon Coast Range	24c Uplifted peneplain on weak rocks, dissected monadnocks of igneous rock
		d Klamath Mountains	24d Uplifted and dissected peneplain on strong rocks, extensive monadnock ranges
		e California Trough	24e Low fluviatile plain.
		f California Coast Ranges	24f Parallel ranges and valleys on folded, faulted, and metamorphosed strata, rounded crests of subequal height
		g Los Angeles Ranges	24g Narrow ranges and broad fault blocks, alluviated lowlands
	25 Lower Californian province	--------	25 Dissected westward-sloping granite upland (in northern part)

• NOTE Major divisions are separated by the heaviest lines. Provinces are named on map and also distinguished by numbers. Sections are indicated by letters. Broken lines indicate boundaries much generalized.

Source: Fenneman, Nevin M., Physical Divisions of the United States, U.S. Department of the Interior, USGS, 1946.

FIGURE III-1

PHYSICAL DIVISIONS OF THE WESTERN UNITED STATES of the volcanic structures are of high geologic interest. The major hazard in this province is from recent volcanic activity. Mt. Lassen erupted over a period from 1914-1921 (Encyclopaedia Britannica, 1975) and could conceivably erupt again, as could other apparently dormant volcanic craters in the province.

On the other hand, the Columbia Plateau Province, although also underlain by large volcanic deposits, provides a soil that is better developed. Excavation would not be difficult, and no apparent hazards exist from faults or volcanoes. The major difficulty encountered in this province is with slope stability. Stream action has cut deep valleys into the weak volcanic rocks. The valley walls are often severely undercut and are quite prone to landslides.

Major Physical Features

Although considerations of the province aid in determining regional hazards, a more specific approach is needed. At the next level, one should examine the major physical features that may pose special problems. These include mountain ranges, ridges, large rivers, lakes and individual mountains. These features are generally constraints, the objectives being to avoid rugged terrain, unstable slopes, ridge lines and large bodies of water. Topography influences what the visual exposure of a line will be, but that aspect is treated in Section V under Esthetics.

Other factors involving topographic conditions include slope and slope aspect. Because of the effect of gravity, steep slopes obviously have a high potential for erosion and landslide. The possibility of landslides is an important consideration. Thick deposits of unconsolidated soils and layers of weak or fractured rocks on steep hillsides are especially susceptible to collapse. Although much slower, erosion is a similar process and is also highly affected by slope. Steep traverses should be avoided wherever possible; if not, special care should be taken during construction to prevent exposed soils from washing away.

Applicable control practices to minimize the disturbance of ground cover include selective cutting, careful design of access roads, mulching, berm placement and sediment basins. Access roads in problem areas should be made longer, with a gentle slope and frequent curves to reduce the possibility of the formation of long, straight water courses during storms. Water bars or water-breaks (runoff diversion structures) may be used to further retard water flow.

Water-breaks are installed at intervals depending on the grade. General guidelines employed by the Bureau of Land Management (BLM) in the West are as follows:

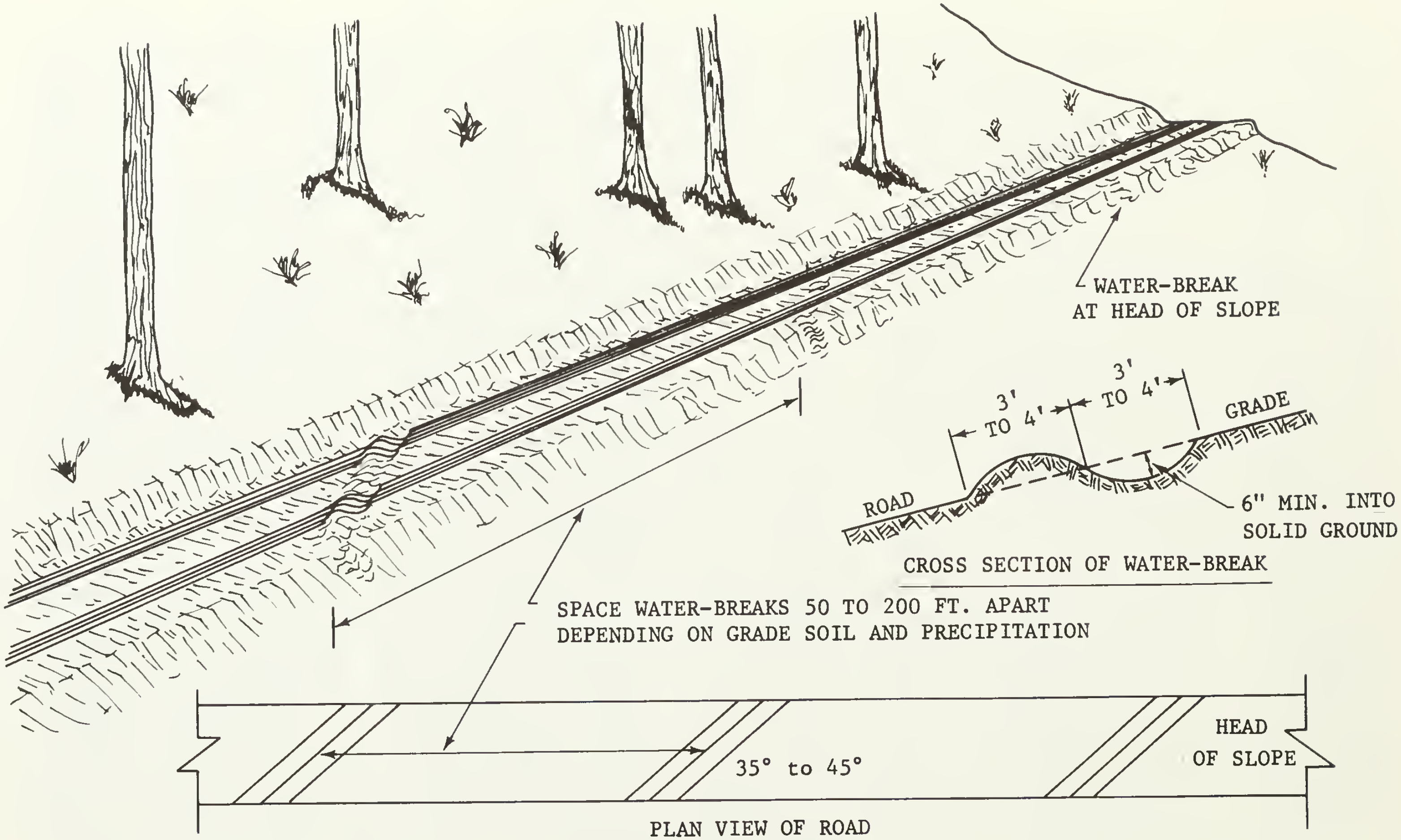
Grade	Interval (in feet)
Less than 2%	200
2 - 4%	100
4 - 5%	75
Greater than 5%	50

The interval between water bars is not strictly a function of slope. A closer spacing should be employed with unstable soils, whereas with very stable soils or rock outcroppings, the intervals may be greater. BLM resolves any question in favor of a conservative or close interval spacing, with a channel grade of 0.002 recommended from the water-break to the natural ground elevations (U.S. Department of Interior, Bureau of Land Management, 1974). Water-break construction is depicted in Figure III-2.

Practice in spacing of water-breaks or water bars varies in different areas. A slightly different set of criteria are given for illustrative purposes in Table III-1.

Slope aspect also influences erodibility. In the Northern Hemisphere, the sun dries out south-facing slopes much more rapidly than northern slopes (other factors being approximately equal). Consequently, less rain will infiltrate the northern slopes, causing increased runoff and, therefore, greater erosion. Slope steepness is also an important constraint in the specific case of slurry pipelines. A maximum grade of 16 to 18 percent must be observed so that the slurry will not clog during periods when the system is shut down. This does not absolutely exclude all areas with slopes greater than 16 to 18 percent, since these areas may be traversed at an oblique angle to the direction of maximum slope. This solution, however, will result in longer pipeline distances and the steep slope may pose a severe erosion problem.

Degree of slope can be obtained either from topographic or soil maps. In mapping an area for a study to determine location or assess impact, the data are frequently grouped into intervals. For example, a constraint map might be prepared in which different colors or degrees of shading distinguish areas with slopes from 0 to 3 percent, 3 to 8 percent, 8 to 15 percent, 15 to 25 percent and over 25 percent; typically, the shading progresses from light to dark as the slope increases. Some studies employ line grids which divide the mapped area into individual "cells" of specified size; such studies may record the percentage of each cell area that falls into each class or interval of slope. These values may later be weighted to take into account slope aspect;



SOURCE: U.S. DEPARTMENT OF INTERIOR, BUREAU OF LAND MANAGEMENT, WYOMING STATE OFFICE, WSO 2800-22D, NOV. 1974.

FIGURE III-2
WATER-BREAK CONSTRUCTION FOR ACCESS ROADS AND DISTURBED SLOPES

TABLE III-1

USE OF WATER BARS FOR STABILIZATION OF ACCESS ROADS.

PER CENT SLOPE OF ROAD	DISTANCE BETWEEN WATER BARS (FEET)
2	250
5	140
10	80
15	60
20	45
25	40
30	35
40	30

SOURCE: Commonwealth Associates Inc., Land Plan Systems Division, Transmission Line Route Selection Environmental Criteria, Jackson, Michigan, 1974.

for example, north-facing slopes might be moved into the class of next greater slope, and south-facing slopes put into a lower class. Alternatively, slope orientation could be accounted for in a subsequent step in the determination of erosion potential (discussed in the next subsection).

PEDOLOGY

Many variables pertaining to soil characteristics influence corridor siting. These include:

- erodibility
- corrosion potential
- color and texture
- fertility
- bearing capacity

The following subsections discuss the major soil factors that influence the suitability of a given area for the installation of a utility line.

Erosion Potential

Soil erosion potential may be estimated using the Universal Soil Loss Equation described by Wischmeier and Smith (1965) and the EPA (1973):

$$A = R\ K\ LS\ C\ P$$

where:

A = soil loss in tons per year

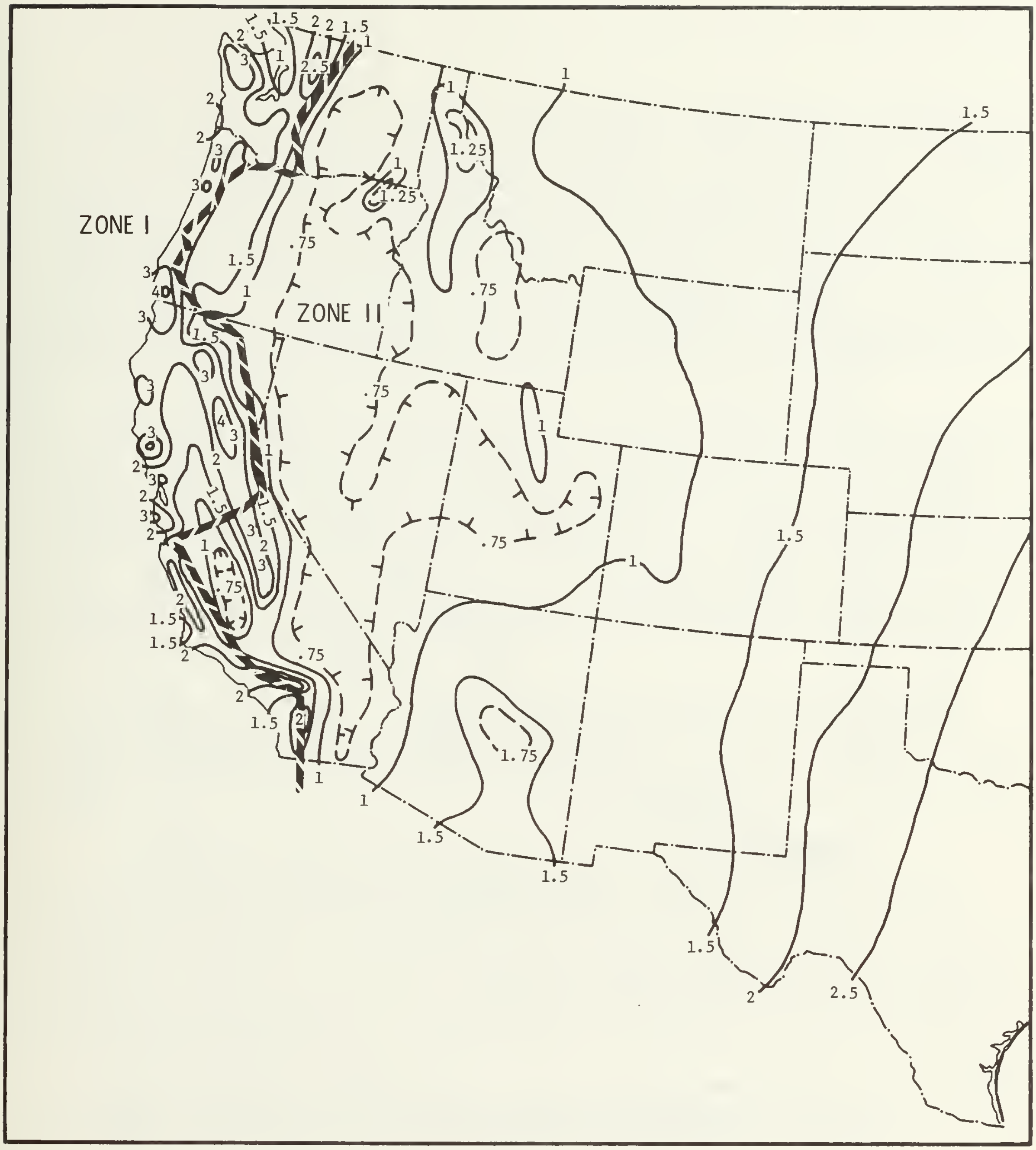
R = local rainfall energy factor

K = soil erodibility factor

LS = slope length factor

C, P = erosion control factors

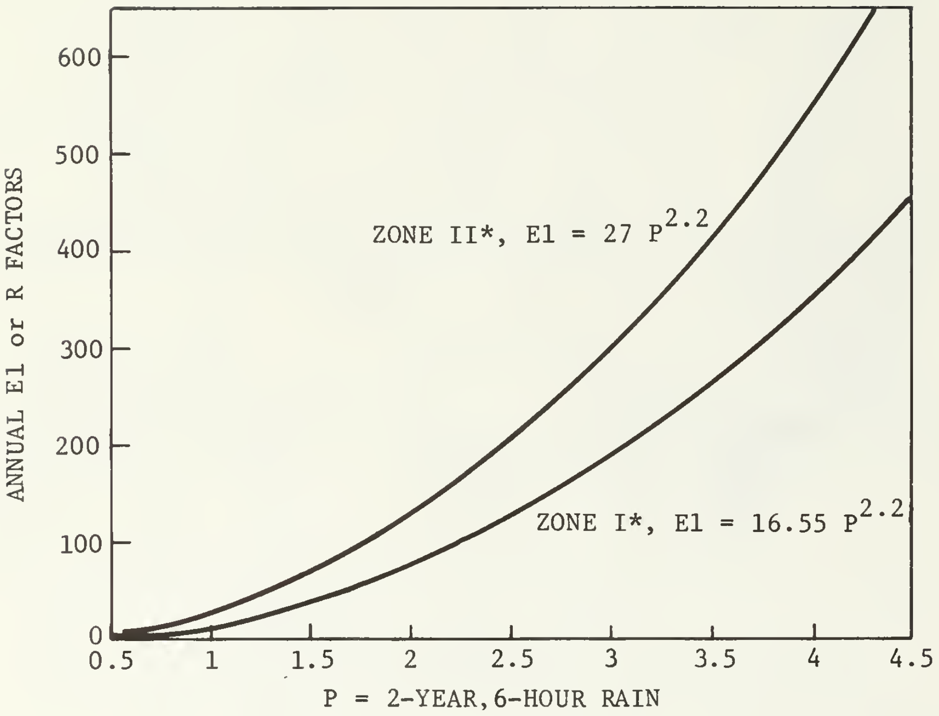
For each rainstorm occurring during a 1-year period, the product of the total kinetic energy in foot-tons per acre times its maximum 30-minute intensity in inches per hour is computed. The value of R is obtained by summing the results of all the individual rainstorm computations in a year. Empirical formulas have also been developed to predict values of R based on the 2-year maximum, 6-hour storm occurring with a frequency of once every two years. The average annual R value may be estimated by obtaining the 2-year, 6-hour rainfall from Figure III-3 and using this value to read R from Figure III-4.



Source: U.S. Environmental Protection Agency, Office of Water Program Operations, Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA-430/9-73-016, Washington, D.C. 1973.

FIGURE III-3

DEPTHS OF THE MAXIMUM 2-YEAR, 6-HOUR RAINFALL (INCHES)



*Rainfall zones are shown in Figure II-2.

Source: U.S. Environmental Protection Agency, Office of Water Program Operations, Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA-430/9-73-016, Washington, D.C., 1973.

FIGURE III-4

RELATION BETWEEN ANNUAL AVERAGE LOCAL RAINFALL ENERGY FACTOR AND THE 2-YEAR 6-HOUR RAINFALL DEPTH FOR TWO RAINFALL ZONES

This soil erodibility factor, K, applies to the particular soil series. The various state soil conservation services are in the process of compiling K factors for the various soils of their states, although some of the work is just beginning. The most common method for estimating K is through comparison with certain benchmark soils whose K values have been accurately measured or through the use of an empirically derived nomograph. Table III-2 lists estimated K values for a group of California soils and Figure III-5 is the nomograph. Figure III-6 is an extremely crude approximation of soil erodibilities based on texture alone. It should be used only as an illustration of the general effects of texture divorced from structure and other considerations.

The slope length factor, LS, combines the degree and length of the exposed soil slope. This factor may be read from Figure III-7. First the slope length (in feet) is found on the horizontal axis, then its intersection with the curve indicating degree of slope, and finally the vertical coordinate that crosses this curve. For example, a slope length of 300 feet intersects the curve at a 14 percent slope to give a soil-loss ratio of 4. Note that slopes up to 20 percent are given as percentages, whereas steeper slopes appear as the ratio of the horizontal dimension (H) to the vertical (V).

C and P represent the fraction of sediment not intercepted by sediment control methods. If no mitigating measures are applied, the values of both C and P are 1.0. Tables III-3 and III-4 contain average values for these factors derived for some common methods of stabilization.

In general, steep, silty, impermeable and unconsolidated soils are most prone to erosion. These soils are often associated with present and former river systems, with some glacial outwash deposits, and with rugged terrain. Sandy, well-sorted, permeable soils, rich in organics, blocky or granular in shape, on gentle-sloping terrain are more erosion resistant. In determining the various local soil types and their characteristics, consultation with the local Soil Conservation Service office may be useful.

Corrosion

Chemical composition, E_H (reduction-oxidation potential, pH, water storage capacity (porosity) and the presence of restrictive layers help determine a soil's potential corrosive effect on a buried pipeline. Corrosion problems for uncoated steel may occur under a variety of soil conditions. Typical conditions that may lead to corrosion include (Uhlig, 1971; and Bechtel Corporation, 1974):

- fine to moderately fine textures
- poor drainage

TABLE III-2

SOIL ERODIBILITY, K, VALUES ESTIMATED FOR SOILS IN CONTRA COSTA COUNTY IN THE WALNUT CREEK WATERSHED CALIFORNIA

MAP SYMBOL	SOIL NAME	SURFACE TEXTURE	K FACTOR		
			SURFACE	SUBSOIL	PARENT MATERIAL*
BN-Zm	Brentwood	Clay loam	0.21	0.33	-
	Zamora	Clay loam	0.23	0.33	-
	Sorrento	Clay loam	0.22	0.35	-
	Los Robles	Clay loam	0.18	0.34	-
BN-Dg	Brentwood	Clay loam	0.23	0.34	-
	Rincon	Clay loam	0.22	0.20	-
	Delhi	Sand	0.03	0.03	-
sy	Sycamore	Silty clay loam	0.31	0.62	-
BN-Rn	Brentwood	Clay loam	0.26	0.37	0.45
	Rincon	Clay loam	0.26	0.18	0.36
CM-Bk	Clear Lake	Clay	0.11	0.18	-
	Botella	Clay loam	0.17	0.40	-
	Salinas	Clay	0.10	0.18	-
Cp-Rn	Cropley	Clay	0.11	0.21	-
	Rincon	Clay loam	0.21	0.13	-
Cp-Rn/B-1	Cropley	Clay	0.10	0.18	-
	Rincon	Clay loam	0.21	0.17	-
Pp	Pescadero	Clay	0.17	0.17	0.19
SX-Sm	Solano	Loam	0.36	0.21	0.33
	San Ysidro	Loam	0.36	0.20	0.31
Sb	Sacramento	Clay	0.13	0.18	0.20

* Parent material erodibility is given for soils with less than 36-inch depth.

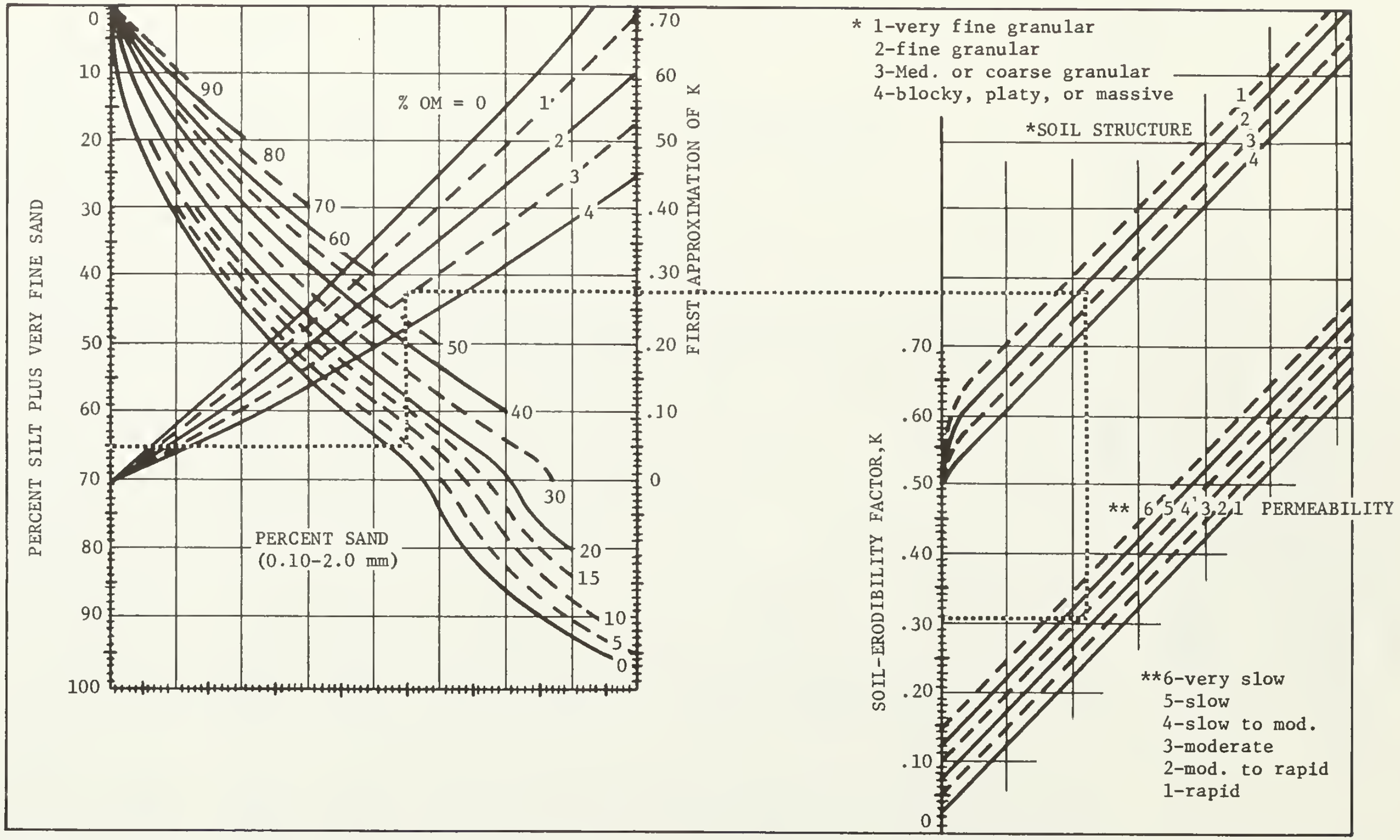
TABLE III-2 (Concluded)

SOIL ERODIBILITY, K, VALUES ESTIMATED FOR SOILS IN CONTRA COSTA COUNTY IN THE WALNUT CREEK WATERSHED CALIFORNIA

MAP SYMBOL	SOIL NAME	SURFACE TEXTURE	K FACTOR		
			SURFACE	SUBSOIL	PARENT MATERIAL*
Sf-Ed	Staten	Peaty muck	0.01	0.01	-
	Egbert	Mucky clay loam	0.01	0.01	-
pw-Ed	Piper	Sandy loam	0.16	0.24	-
	Egbert	Mucky clay loam	0.11	0.16	-
Dg/Bc-2	Delhi	Sand	0.02	0.02	-
TI-Ax/BD-2	Tierra	Loam	0.30	0.21	0.31
	Antioch	Loam	0.31	0.28	0.31
Pm-Km	Perkins	Clay loam	0.28	0.22	0.15
	Kimball	Clay loam	0.28	0.28	0.29
Dl-An/DE-2	Diablo	Clay	0.11	0.18	-
	Altamont	Clay	0.11	0.18	-
Dl-An/F-2	Diablo	Clay	0.11	0.18	-
	Altamont	Clay	0.11	0.18	-
An-SF/DE-2	Altamont	Clay	0.11	0.18	-
	San Benito	Silty clay loam	0.28	0.41	-
	Linne	Clay loam	0.14	0.32	-
An-SF/F-2	Altamont	Clay	0.11	0.18	-
	San Benito	Silty clay loam	0.28	0.41	-
LE-Ge/FG-2	Los Gatos	Loam	0.28-0.24	0.33	-
	Gaviota	Sandy loam	0.23-0.17	0.22	-
	Sobrante	Clay loam	0.18-0.13	0.32	-
LF-MI-FG-2	Los Osos	Clay loam	0.25-0.21	0.18	-
	Millsholm	Loam	0.27-0.22	0.33	-
	Gazos	Silt loam	0.27-0.22	0.29	-
cv-LF/F-2	Climara	Clay	0.14	0.18	-
	Los Osos	Clay loam	0.25	0.22	-
AE/DE-2	Arnold	Loamy sand	0.12	0.12	-

* Parent material erodibility is given for soils with less than 36-inch depth.

Source: U.S. Environmental Protection Agency, Office of Water Operations, Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA 430/9-73-016, Washington, D. C., 1973.



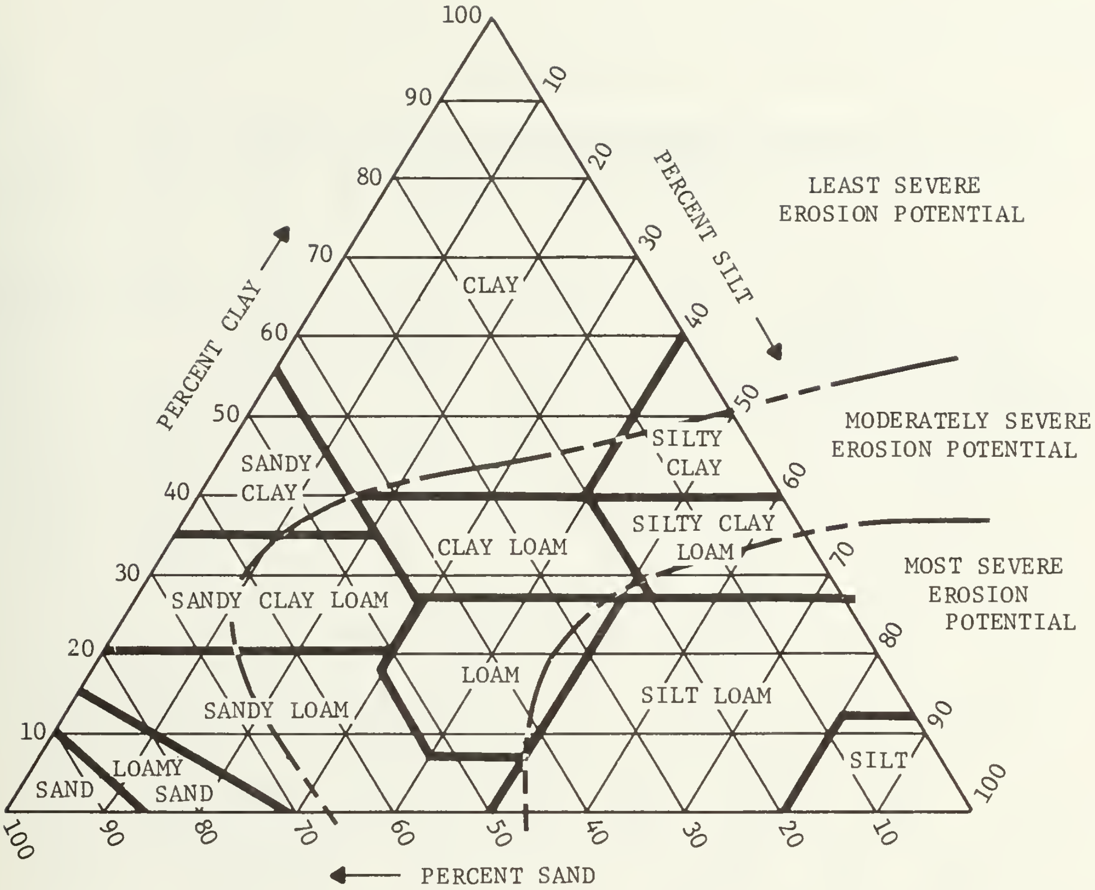
W. H. WISCHMEIER, ARS-SWC, PURDUE UNIV. 2-1-71

PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure,and permeability,in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: silt 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

Source: Wischmeier, Johnson and Cross, "A Soil Erodibility Nomograph for Farmland and Construction Sites," Journal of Soil and Water Conservation, Vol. 26, September - October 1971, pp. 189

FIGURE III-5

NOMOGRAPH FOR ESTIMATING K-VALUES OF SOILS

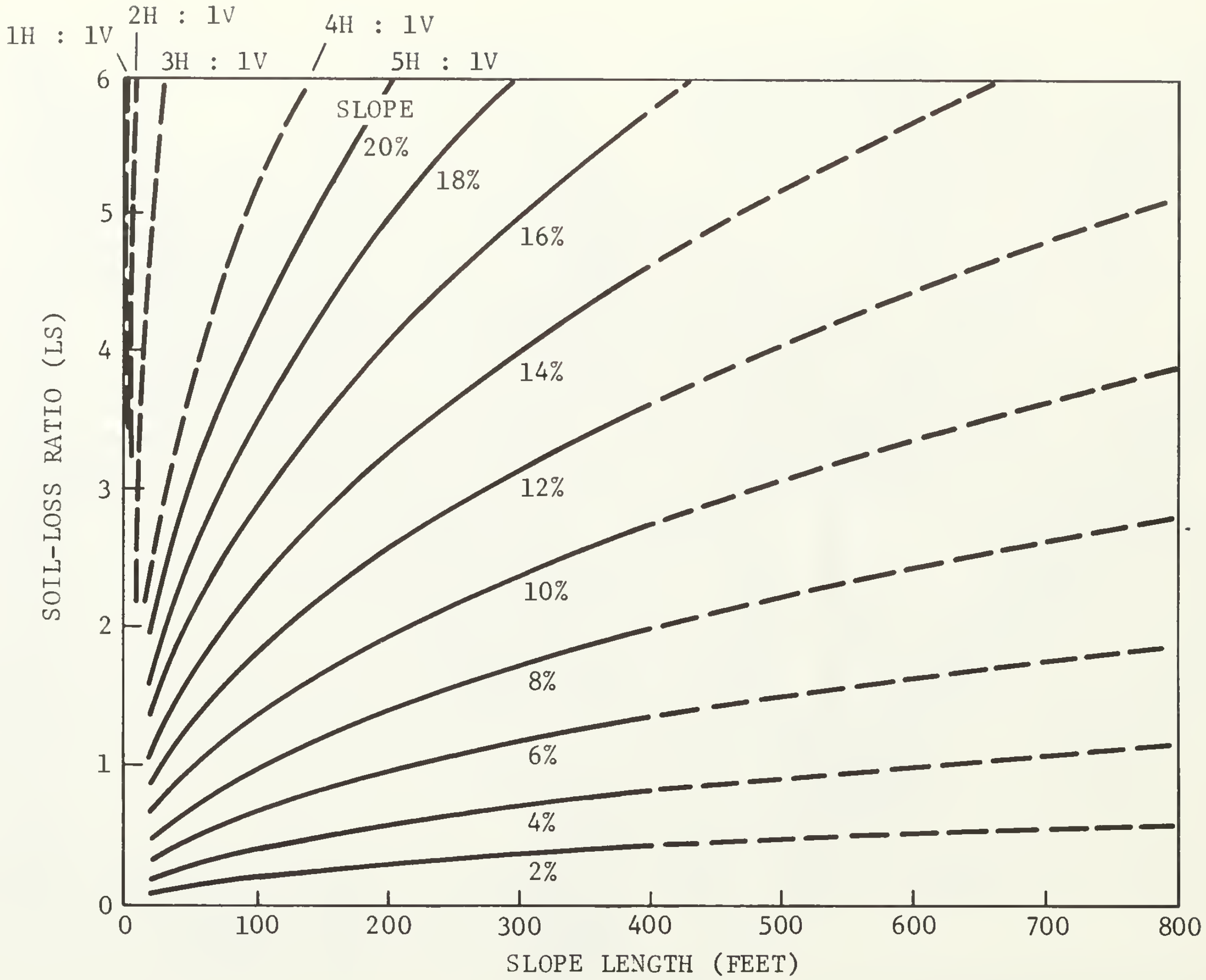


SOIL SEPARATE	PARTICLE DIAMETER (mm)
Very Coarse Sand	2.00-1.00
Coarse Sand	1.00-0.50
Medium Sand	0.50-0.25
Fine Sand	0.25-0.10
Very Fine Sand	0.10-0.05
Silt	0.05-0.002
Clay	Less Than 0.002

Source: U.S. Department of Agriculture, Soil Conservation Service, Guide for Interpreting Engineering Uses of Soils, with modifications, 1971.

FIGURE III-6

APPROXIMATE EROSION POTENTIALS OF VARIOUS TEXTURES



Source: U.S. Environmental Protection Agency, Office of Water Program Operations, Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA-430/9-73-016, Washington, D.C., 1973.

FIGURE III-7

SLOPE EFFECT CHART

TABLE III-3

AVERAGE FACTOR C VALUES FOR VARIOUS SURFACE STABILIZING TREATMENTS

TYPE OF TREATMENT	TIME ELAPSED BETWEEN SEEDING AND BUILDING	
	None*	6 Months**
Seed, fertilizer and straw mulch, Straw disked or treated with asphalt or chemical straw tack.	0.35	0.23
Seed and fertilizer	0.64	0.54
Chemicals (providing 3 months protection)	0.89	--
Seed and fertilizer with chemicals (providing 3 months protection)	0.52	0.38
Chemical (providing 12 months protection)	0.56	--
Seed and fertilizer with chemical (12 months protection)	0.38	--

*Assumes 18-month construction period.
**Assumes 24-month construction period.

Source: U.S. Environmental Protection Agency, Office of Water Program Operations, Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA-430/9-73-016, Washington, D.C., 1973.

TABLE III-4

FACTOR P VALUES FOR COMPONENTS OF EROSION AND SEDIMENT CONTROL SYSTEMS

COMPONENT	FACTOR P VALUE
Small sediment basin: (0.04 ratio)	
Sediment from 70% construction area	0.50
Sediment from 100% construction area	0.30
Downstream sediment basin: (0.06 ratio)	
With chemical flocculants	0.10
Without chemical flocculants	0.20
Erosion reducing structures:	
Normal rate usage (165 ft. per acre)	0.50
High rate usage (over 165 ft. per acre)	0.40

Source: U.S. Environmental Protection Agency, Office of Water Program Operations, Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA-430/9-73-016, Washington, D.C., 1973.

- fluctuating water tables
- poor permeability
- electrical conductivity in excess of 1000 μmhos/cm or electrical resistivity less than 100 ohm-cm
- total acidity greater than 12 mg per 100 grams of soil
- pH less than 5
- high amounts of sulfides and easily weathered minerals
- organic-rich peat or muck soils, especially if there is a high water table.

The probability of corrosion is also high where a pipeline intersects two adjacent soil types or where several types are mixed as backfill. Corrosion is closely related to water quality. Further considerations on corrosion are discussed in the subsection dealing with water quality. It should be noted that corrosive soils do not necessarily constitute a valid exclusion criterion since corrosion-limiting methods, such as galvanizing and cathodic projection, are commonly used. In areas of extreme corrosion potential, fiberglass or plastic pipe may be utilized.

Other Soil Characteristics

Soil color helps determine the degree of contrast and, therefore, the visibility of the access roads. Fertility and slope determine a soil's agricultural suitability and may indicate areas where the construction and maintenance of a utility corridor would interface with productive agricultural uses. This is discussed in relation to land use in Section V. These factors also provide a means to estimate the rate at which an exposed area will regain its vegetation. Fertility is generally qualitatively based on the depth, texture, drainage, and organic matter contained in the soil. Soil series descriptions including these factors may often be found in the soils handbooks published by the Soil Conservation Service (SCS), U.S. Department of Agriculture, or from local SCS offices in the region of interest, or may be determined through field studies.

Foundation Capability

A major consideration is the soil's engineering properties, which affect its ability to support towers or pipelines. Important properties include:

a. soil density;
b. the liquid limit, defined as the moisture content at which the soil becomes fluid;
c. the plasticity index, defined as the range of moisture within which the soil is in a plastic or semi-solid condition; and
d. the shrink-swell potential, or the change in volume to be expected with a change of moisture content.

The moisture content at which the soil becomes plastic is the difference between the liquid limit and the plasticity index (plastic limit = liquid limit - plasticity index). If the plastic limit or the liquid limit of a soil is low, that soil is prone to foundation problems unless the foundation is seated deeply. Shrink-swell potential can be measured as the coefficient of linear extensibility (COLE). The USDA (1971) rates soil in three classes of shrink-swell potential: low, <0.03 COLE; moderate, 0.03-0.06 COLE; and high, >0.06 COLE. Soils that are rich in fine silts and clays or with high concentrations of organic matter frequently have a high shrink-swell potential and/or low plastic limit. The clay mineral montmorillonite is especially susceptible to swelling on contact with water. In addition to swelling or slipping when they are water saturated, these soils are prone to subsidence problems when they dry out, either through drought or extensive dewatering. Table III-5 is a general guide for classifying engineering properties based on soil texture. Areas of permafrost are also subject to subsidence if they begin to thaw. In these cases, subsidence is due to oxidation and compaction of the soil particles.

Fortunately, most of these factors are reasonably consistent within a particular soil series. Many states have completed or are in the process of mapping the extent of the soils in their state and tabulating their characteristics. The soil descriptions accompanying these maps generally include most of the data needed for a corridor selection study. It is unlikely that detailed soil surveys would need to be initiated as part of the environmental review, but emphasis should be placed on sound engineering practices to minimize erosion during construction.

In determining where a line should be placed, similar soils may be combined according to their characteristic erodibility, fertility, corrosion potential and construction suitability and mapped as overlays. Alternately, the suitability of each soil may be ranked in all four categories, the scores for one cell (or unit of area) being the average scores of the soil in each category in that cell.

TECTONISM

Tectonism is the set of natural processes related to the creation, movement, and subsequent deformation of the Earth's crust. The forces involved in these processes are tremendous and easily able to wreak havoc on the relatively fragile structures built by men.

Tectonic forces, such as crustal plate movements, tend to slowly build up enormous stress which, after reaching a critical point, can suddenly be relieved causing violent earthquakes. This seismic activity also produces the secondary phenomenon called tsunami, or tidal waves. Other violent expressions of tectonism are volcanoes and geothermal

TABLE III-5

GENERAL RELATIONSHIP OF SYSTEMS USED FOR CLASSIFYING SOIL SAMPLES

USDA CLASS AND SYMBOL	UNIFIED SYMBOL	AASHO SYMBOL	SOIL PROPERTIES RELATED TO CLASSIFICATIONS
Clay; silty clay "c"; "sic"	CH	A-7	High shrink-swell clays.
	MH	A-7	Mica, iron oxide, kaolinitic clays.
	CL	A-7	Low LL. Generally <45 pct clay.
Silty clay loam "sicl"	CL	A-7	Low LL. Plastic. (A-6 if clay <30 pct).
	ML-CL	A-7	Low LL. Mod. plastic. (A-6 if clay <30 pct).
	CH	A-7	High LL. High shrink-swell clays.
	MH	A-7	High LL. Mica, iron oxide, kaolinitic.
Clay loam "cl"	CL	A-6 or A-7	Low LL. Plastic.
	ML-CL	A-6	Low LL. Moderately plastic.
	CH	A-7	High LL. High shrink-swell clays.
	MH	A-7	High LL. Mica, iron oxide, kaolinitic.
Loam "l"	ML-CL	A-4	Moderately plastic (A-6 if clay> 21 pct).
	CL	A-6	Plastic (A-4 if clay < 22 pct).
	ML	A-4	Low plasticity (A-7 if clay> 21 pct).
Silt loam "sil"	ML-CL	A-4	Moderately plastic (A-6 if clay> 21 pct).
	ML	A-4	Low plasticity (A-7 if clay> 21 pct).
	CL	A-6	Plastic.
Silt - "si"	ML	A-4	Low plasticity.
Sandy clay "sc"	CL	A-7	Fines> 50 pct.
	SC	A-7	Fines 50 pct or less.
Sandy clay loam "scl"	SC	A-6	Plastic. Fines 36-50 pct.
	SC	A-2-6	Plactic. Fines 35 pct or less.
	CL	A-6	Plastic. Fines> 50 pct.
Sandy loam "sl"	SM	A-2-4 or A-4	Low plasticity.
	SC	A-2-4	Plastic.
	SM-SC	A-2-4	Moderately plastic.
Fine sandy loam "fsl"	SM	A-4	Nonplastic. Fines 50 pct or less.
	ML	A-4	Nonplastic. Fines > 50 pct.
	ML-CL	A-4	Moderately plastic. Fines> 50 pct.
	SM-SC	A-4	Moderately plastic. Fines 50 pct or less.
Very fine sandy loam "vfsl"	ML-CL	A-4	Moderately plastic.
	ML	A-4	Low plasticity.
Loamy sands "ls"; "lfs" "lvfs"	SM	A-2-4	Nonplastic. Fines 35 pct or less.
	SM-SC	A-2-4	Moderately plastic. Fines 35 pct or less.
	SM	A-4	Low plasticity. Fines> 35 pct.
	ML	A-4	Little or no plasticity.
Sand; fine sand "s"; "fs"	SP-SM	A-3	Fines approx. 5-10 pct.
	SM	A-2-4	Fines approx. > 10 pct.
	SP	A-3	Fines< 5 pct.
Very fine sand "vfs"	SM	A-4	Low plasticity.
	ML	A-4	Little or no plasticity.
Coarse sand "cs"	SP; GW	A-1	Fines< 5 pct.
	SP-SM	A-1	Fines 5-12 pct.
	SM	A-1	Fines 13-25 pct.
	SM	A-2-4	Fines >25 pct.
Gravel, "G" 50 pct passes No.200 50 pct of coarse passes No. 4 sieve	GP; GW	A-1	Fines< 5 pct.
	GM or GC	A-1	Fines 5-25 pct.
	GM or GC	A-2	Fines 26-35 pct.
	GM	A-4	Fines> 35 pct.
	GC	A-6	Fines> 35 pct.

Source: U.S. Department of Agriculture, Soil Conservation Service, Guide for Interpreting Engineering Uses of Soils, 1971.

activity, caused by frictive heating of the lower crust mantle. Although seldom a problem in determining line location, all four of these phenomena may need to be considered in specific geographic areas.

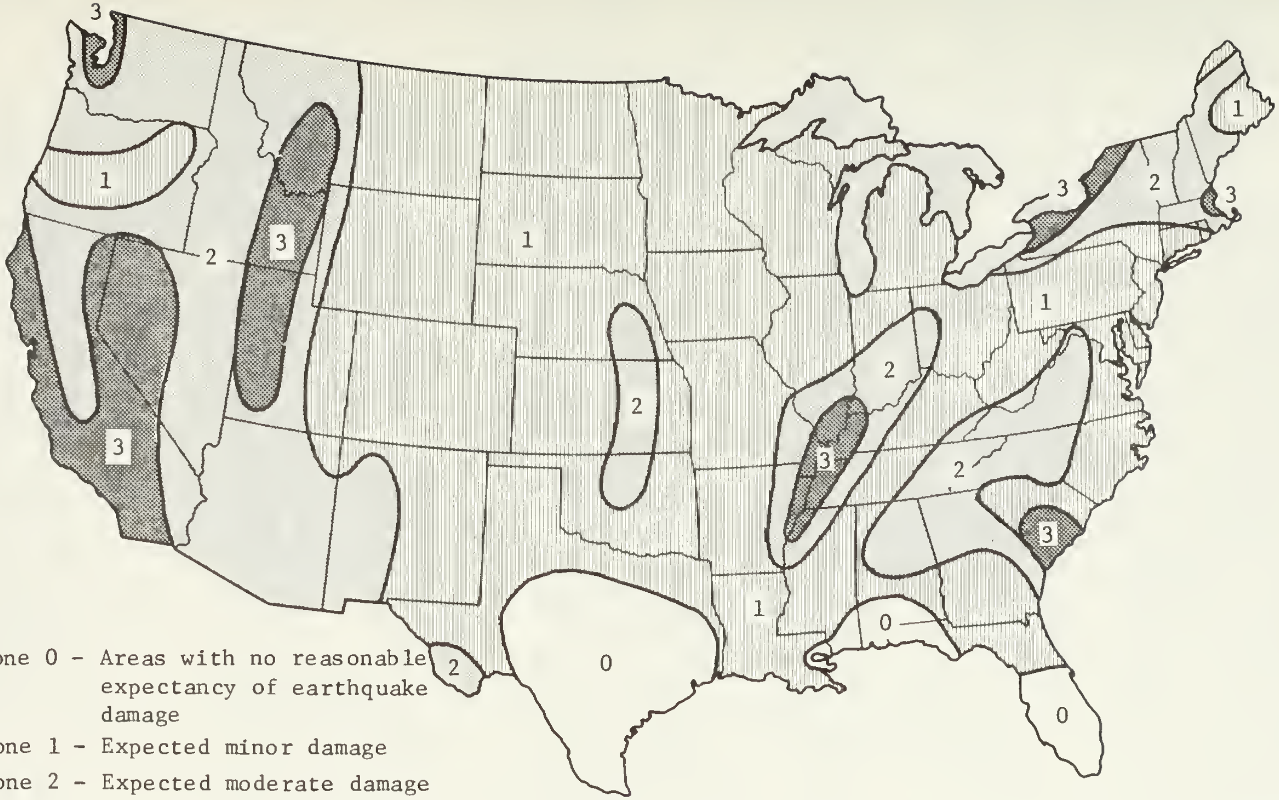
Earthquakes

Since earthquakes are among the most feared and the most destructive of the natural disasters, any siting study should examine the seismic potential of candidate routes. Since tectonic forces generally act at centers of weakness in the crust, it may eventually be possible to predict the exact location and times of seismic activity; but, at present, this ability is very limited. Until then, more conventional methods should be used. Two steps are involved. The first, which is recommended for all areas, requires identification of tectonic forces from available data. Field investigation to identify and map all faults in the area is probably worth the time and effort only in areas of high seismic activity. The displacement and age of faults should be estimated in such regions. The presence of an ancient fault does not necessarily endanger a nearby utility. If the area has no recent activity and is sufficiently removed from active areas, it may be an acceptable location.

The second step is important for areas of high earthquake risk. Figure III-8 shows the seismic risk zones of the United States as determined by the National Oceanic and Atmospheric Administration. The second step should be carried out for Zone 3, regions where major destructive earthquakes may occur, and may be useful for Zone 2, regions of expected moderate damage. This step involves an examination of the recorded history of the surrounding areas and tabulation of all earthquakes felt in the study area, their magnitudes, epicenter locations and focal depths (if known). If there is a history of much earthquake activity accompanied by severe damage, these data may be used to perform a probability analysis to determine the seismic potential of alternate routes. An example of a simple statistical analysis is given by Westinghouse (1973).

This Westinghouse study determined the frequency or mean return time of events of a given magnitude using a method described by Lomnitz (1966). This method ranks the events by magnitude, comparing them to a Poisson distribution of random events. The data are then fitted to the Richter equation, which may be used to determine the modal magnitude, which is the magnitude of the event that may be expected to be exceeded in 63 percent of the years in the area from which the data were taken.

A detailed study of earthquake potential is time-consuming and is usually not warranted except in areas with a history of significant damage. In those situations, the information developed can be used in



Zone 0 - Areas with no reasonable expectancy of earthquake damage
Zone 1 - Expected minor damage
Zone 2 - Expected moderate damage
Zone 3 - Where major destructive earthquakes may occur

Source: Executive Office of the President, Office of Emergency Preparedness, Report to the Congress, Disaster Preparedness, January 1972.

FIGURE III-8

SEISMIC RISK MAP FOR CONTERMINOUS UNITED STATES the design process to ensure that the structures will be able to withstand any earthquake likely to occur, maximizing the system reliability.

Two systems are used to quantify the magnitude of an earthquake. The modified Mercalli scale, expressed in Roman numerals from I to XII, is a relative measure of the intensity of an earthquake. It is based on observed destruction and, therefore, decreases with distance from the earthquake center. It also varies with the soils and water content. An intensity of IX is sufficient to break underground pipes while an intensity of VIII will knock down towers. Table III-6 shows the observed effects that define the modified Mercalli scale.

The Richter scale is a measure of energy released as determined by the amplitude of surface waves. It indicates the magnitude of an earthquake at its epicenter. It is customary to represent the values in decimal notation. Table III-7 gives the approximate equivalents between the Mercalli and Richter scales. The destruction caused by an earthquake rated at the Richter maximum of 9 is tremendous in the area of its epicenter, but decreases with distance to a point where it is barely felt. (For such a large earthquake, this distance would be more than 1000 miles.) Table III-8 lists the magnitudes and associated displacements of some recent earthquakes.

In siting some utility lines, such as the Alaska pipeline, it may be impossible to avoid seismically active zones. In such instances, structures must be carefully designed to withstand the forces that may occur. The magnitudes of the estimated 50- and 200-year earthquakes for various segments along its length were used for the design of the Alaska pipeline. Ground motion values for each magnitude were derived from historical data from other events. A detailed discussion of this procedure may be found in Page _et al_. (1972).

Tsunamis are huge tidal waves caused by undersea or nearshore earthquakes. They can range up to 200 feet in size and travel at speeds up to 400-500 miles per hour. These tremendously destructive waves are a hazard only in coastal areas. The Office of Emergency Preparedness (1972) designated the tsunami danger zone as all areas within one mile of the coast and lower than 100 feet above sea level.

Volcanoes

Volcanoes do not present a potential threat to utilities over long distances as do earthquakes, but, when they occur, they can be quite destructive locally. In the United States, the danger from volcanoes is quite remote compared to other hazards. The National Atlas (U.S. Department of the Interior, Geological Survey, 1970) maps 17 volcanoes and 12 calderas in the Continental United States (a caldera is an enlarged volcanic crater). Of these, 15 volcanoes, all in the Cascade Mountain range between northern California and Washington

TABLE III-6

MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITY

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration may be estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, column monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well-water levels. Disturbs persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

TABLE III-6 (Concluded)

MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITY

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks.

XI. Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completedly out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Source: Flawn, Peter, Environmental Geology-Conservation, Land-Use Planning and Resource Management, Harper and Row, New York (1970)

TABLE III-7

APPROXIMATE EQUIVALENTS BETWEEN RICHTER AND MERCALLI SCALES

RICHTER MAGNITUDE	MERCALLI INTENSITY (NEAR SOURCE)
2	I-II
3	III
4	IV-V
5	VI-VII
6	VII-VIII
7	IX-X
8	XI
9	XII

Source: Westinghouse Environmental Systems, Colstrip Generation and Transmission Project, Applicant's Environmental Analysis, November 1973.

TABLE III-8

LENGTH AND AMOUNT OF OBSERVED DISPLACEMENT RELATED TO EARTHQUAKES IN CALIFORNIA, NEVADA, AND BAJA CALIFORNIA

DATE	LOCATION	RICHTER MAGNITUDE	OBSERVED DISPLACEMENT				
			LENGTH (MILES)	MAX.VERT. COMPONENT	MAX.HORIZ. COMPONENT	MAX.TOTAL ACROSS ZONE	DISPLACEMENT BY RESURVEYING
1857	Fort Tejon, Calif.	7.75	40-250	?	Large		
1868	Hayward, Calif.	7	?	?	Some		
1872	Owens Valley, Calif.	7.75	ca. 50	13'	18'		
1899	San Jacinto, Calif.	ca. 6.75	ca. 2	?	?		
1906	San Francisco, Calif.	8.3	190 or 270	3'	21'[a]	16'	
1915	Pleasant Valley, Nev.	7.6	24	15'	--	15'	
1932	Cedar Mtns., Nev.	7.3	38	24"	34"	35"	
1934	Excelsior Mtns., Nev.	6.5	0.85	5"	--	5"	
1934	Colorado River delta, Baja Calif.	7.1	?	?	?	?	
1940	Imperial Valley, Calif.	7.1	40	--	19'	19'	ca. 9' Horiz.
1947	Manix, Calif.	6.2	1	--	3"	3"	
1950	Fort Sage Mtns., Calif.	5.6	5.5	5"-8"	--	8"	
1951	Superstition Hills, Calif.	5.6	1.9	--	Slight	Slight	
1952	Kern County, Calif.	7.7	40	4'	2'-3'	3.6'	1-2' Horiz. 1-2' Vert.
1954	Rainbow Mtns., Nev.	6.6	11	12"	--	12"	
1954	Fallon, Nev.	6.8	14	30"	--	30"	
1954	Fairview Peak, Nev.	7.2	35	14'	12'	18.5	ca. 8' Horiz. ca. 4' Vert.
1954	Dixie Valley, Nev.	6.9	31	7'	7'	7'	ca. 7' Vert.
1956	San Miguel, Baja Calif.	6.8	12	36"	31"	36"	
1966	Parkfield, Calif.	5.6	ca. 25	--	4"	4"[b]	

*Source: Flawn, P., Environmental Geology-Conservation, Land-Use Planning and Resources Management, Harper and Row, New York, 1970.

[a] The commonly cited 21' is partially attributable to lurching.

[b] Displacement is continuing in association with individual aftershocks.

(Figure III-9), are, geologically speaking, relatively recent. They date from the Quaternary Age (younger than 2.5 million years); only one, Mt. Lassen in California, is historically recent. It erupted between 1916 and 1921 (Encyclopaedia Britannica, 1975). The others are Mesozoic (approximately 60 to 200 million years). Older volcanoes are mapped in Arizona and New Mexico, while the calderas are scattered through Colorado, Nevada, California and New Mexico. Alaska has 48 volcanoes and 5 calderas, all along the Pacific coast, one half of them in the Aleutian Islands. Hawaii has 11 volcanoes and 3 calderas decreasing in age toward the southeast. Although a volcano may have been dormant for long periods of time, it is not necessarilly inactive (as the eruption of Mt. Lassen indicates).

The most devastating products of volcanic eruption are ash flows, lava flows and mud flows. Although destructive, lava flows are quite short range. Mud flows, however, may travel great distances and cause widespread destruction. They are composed of melted snow and ice, mixed with tephra and local soils; and tend to follow natural drainage patterns. A mud flow from Mt. Rainier is 70 miles long and tens of feet deep. These phenomena are rare but, nonetheless, are possible.

Geothermal Areas

Recent emphasis has been placed on the development of geothermal areas as power sources and, in such a situation, these areas will require utility lines. For example, a generating plant using a geothermal source for energy would be built as close to the source as possible and the transmission line would proceed from the center of the area. However, utility lines linking other points would, in general, not be well placed in crossing a geothermal area that they did not directly serve. In the first place, the utility corridor would represent some inconvenience, if not impedance, to subsequent exploitation of the geothermal resource(s). Secondly, the hot and often extremely saline geothermal springs are high both in corrosion potential and electrical conductivity, which are particularly unfavorable to buried structures such as pipelines. It is difficult to estimate the minimum allowable distance of approach to these areas, as this depends to a large degree on the structure of the bedrock and the type of geothermal activity. Safe distances represent an engineering and geologic determination that the utility should undertake.

OTHER GEOLOGIC CONSIDERATIONS

Three additional aspects of geology have a direct bearing on the location of utility lines: bedrock characteristics, geologic hazards (other than tectonic activity) and mineral resources.

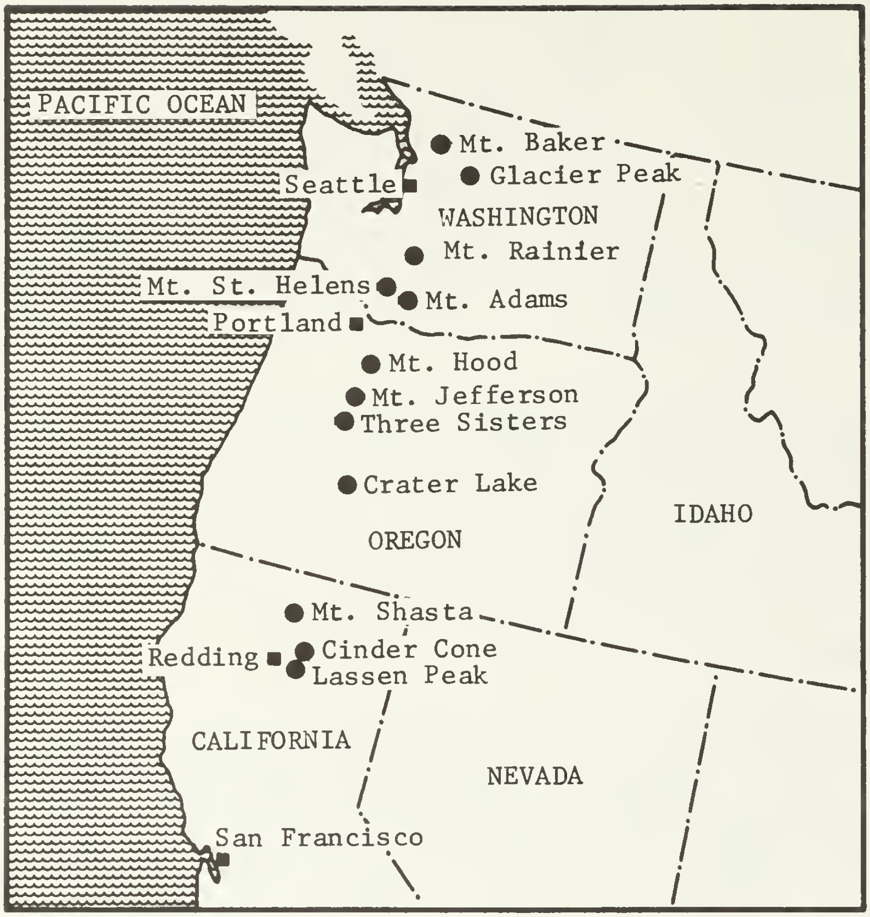


FIGURE III-9

DORMANT VOLCANOES OF THE PACIFIC NORTHWEST

Source: Executive Office of the President, Office of Emergency Preparedness, Report to the Congress Disaster Preparedness, January 1972.

Bedrock Characteristics

Bedrock characteristics of concern to utility corridors include depth, hardness, strength, condition and stability. These affect tower foundation stability, drainage, and the ease with which pipelines can be buried. Shallow, hard bedrock can provide a good foundation for utility towers, but requires blasting and considerable expense for pipeline construction.

One way to evaluate many general geologic effects is based on the depth to the bedrock. In areas where the overlying soil is thick, the effects of the bedrock are less significant, while the effects of the soil become increasingly important. Additional information on the bedrock is important where the soils are shallow. In these areas, the formations could be categorized by their relative stabilities, foundation strength and trenching problems.

Geologic Hazards

Formation stability, condition, slope and water content help determine landslide potential. It is important to recognize the presence of over-steepened slopes. These usually occur as a result of undercutting by either natural processes, as in the case of a stream cutting out a deep, narrow valley, or by man's intrusion, as in the case of deep road cuts made at the base of an already steep hillside. Another condition that favors landslides is weak, thin-layered strata that dip parallel to or at a slightly shallower angle than the hillside. These have a tendency to break off and slide down a slope, especially if they become saturated with water, due to either a high water table or a sudden storm. Poor drainage is, therefore, a third condition conducive to slope failure. Thick deposits of soil with high shrink-swell potential on relatively steep slopes are another cause for slope instability. The intense vibration of large earthquakes can also cause huge landslides in areas that would not normally be prone to such problems. Any slopes that appear excessively steep should be marked for further study, especially if they are cut at the bottom by either a stream or a road, contain thick clay deposits, or are in a high seismic risk area.

The amount and type of jointing, foliation and weathering associated with the presence of escarpments indicates the possibilities for large slumps or rock falls. These are distinguished from landslides in that the fallen material acts as individual particles rather than avalanching mass movement associated with a landslide. The effects of this phenomenon are usually confined to the base of the cliff, where a talus is formed. Corridors should avoid the immediate area at the base of the cliff as well as the upper edge, as the cliff face will migrate into the hill over time.

Another important type of geologic hazard is bedrock subsidence. This is usually, but not always, associated with former subsurface extractive operations. It is also a possibility wherever there are large caverns or tunnels in the rock. This type of subsidence is distinct from that described in the pedology section. The former is concerned with the compaction of soils through rearranging the soil particles to fill the void space in the soil structure. Subsidence in this case is the result of the collapse of cavern ceilings and down warping of the overlying rock structures. Possibilities for bedrock subsidence exist wherever there are limestone caverns, extensive groundwater withdrawals or subsurface mining operations, so these areas should be noted and mapping may be required. As the dangers involved to utilities are not great unless the caverns are very large, it will usually suffice to note the presence of such conditions so that the utilities may be designed to withstand any stresses caused by the largest possible subsidence.

Mineral Resources

The presence of mineral or metallic ores and of oil and natural gas fields affects the route in that a utility line not directly serving mineral extracting may interfere with the exploitation of the resources. It is, therefore, necessary to assess the economic potential of any possible resource deposits and their relation to the corridor.

Valuable resource areas may be ranked by value and mapped as possible constraints in the corridor selection process.

WATER SYSTEMS

Surface Waters

Utility corridors by themselves have little effect on water systems once they are in place. The major effects of a corridor occur during its construction. During this time, construction activities may disrupt or even permanently alter drainage patterns and stream channels; or in some situations, it might degrade the stream quality to a point where it is no longer fit for its present or planned uses and cannot adequately support its original aquatic community. Water quality degradation is usually due to increased turbidity from sediment-laden runoff and from resuspension of bottom sediments during trenching, but may also include chemical pollution in the form of nutrients and heavy metals, both of which are often contained in the undisturbed sediments. Chemical pollution may also result from the use of pesticides and herbicides in the ROW and from runoff from construction wastes, such as rusting metals and spilled or discarded oils.

Floodplains represent an important consideration in corridor locations. Flooding can expose buried pipelines, rendering them vulnerable to possible rupture by floating debris. Power lines are also faced with severe hazards, such as undermined towers and accidental grounding, that justify their location away from areas prone to flooding. Although it is desirable to avoid floodplains, it is usually impossible to route a long corridor without crossing any major river and, unfortunately, almost every major river is occasionally subject to flooding. Certain rivers or river segments are more likely to flood than others and these should be identified. All areas where a corridor must cross major rivers should be carefully examined for flooding potential and probable flood stages. Pipelines may be protected by locating them in areas where scouring action (turbulent flow) would be minimal during flooding and by weighting the pipes to prevent them from floating out of their trench if exposed. In difficult situations, the feasibility of pipeline suspension spans high over river canyons should be considered, although this is an expensive and highly visible alternative.

General surface water factors that should be considered with respect to the location of a corridor in a study area include a list of the types of water bodies present, their size, location, orientation, discharge, conductance, corrosion potential and use. A possible classification system could divide water-covered areas into rivers and waterways too large to span without intermediate towers, large lakes and reservoirs (greater than 40 acres); bays and estuaries; and small lakes, ponds, streams and other water bodies that may be easily spanned or avoided.

If lakes are very large they are often formulated as study area boundaries or binding constraints. This is due not to the impossibility of crossing them, but to high costs, disruption of water quality, high visual impact, resultant inaccessibility and the possibility of corrosion damage. In addition, the environmental effects cannot always be completely ascertained. It is useful, therefore, to avoid lakes and reservoirs when it is possible to use locations equally suitable on other grounds. Bays and estuaries present similar problems with a greater possibility of corrosive action on a submerged pipe. There are, however, many exceptions to this guideline. Powerlines have been constructed across shallow lakes and bays, and pipelines are often laid offshore or across bays. In these cases, water depth is an important factor since construction costs increase with depth.

The size of a water body is important for other reasons, as well. A river with a large drainage area is susceptible to flooding from the cumulative effect of prolonged heavy rainstorms or spring thaws. On the other hand, a confined stream with a small drainage area, such as a canyon in a desert region, is prone to flash floods. Streams with high flow velocities have the energy to erode deep channels and carry large abrasive sands that can scour pipe wrappings and undercut transmission towers. Streams with low discharges cannot transport large masses of material and will be forced to deposit any additional sediment load from erosion originating at upstream construction sites. This could clog the stream and have severe effects on local aquatic life. On the other hand, high discharge streams and rivers have the capacity to carry large volumes of sediments. These are usually deposited whereever the stream velocity suddenly decreases-- for instance, at the inlet to a lake or reservoir. Such deposits can eventually completely fill these reservoirs, rendering them useless as water storage areas. In general, streams and rivers tend to flow at an equilibrium sediment concentration. Any disruption of the flow pattern can severely disturb this equilibrium, causing increased scour or deposition downstream in addition to disrupting the stream ecology. Streamflow changes or increased sediment loads caused by construction activity can also affect man's use of the stream or lake involved, especially if the water was originally of high quality. It is, therefore, imperative to use construction techniques that minimize the possibilities for siltation or other hydrologic disturbance.

Corridor construction at stream crossings introduces sediments to the stream in two ways. One is by removing the vegetation from the land surface to create access roads, to trench or to provide clearance for power line sag. Removal of the vegetation, which stabilizes the soil, can lead to substantial erosion. This effect should be mitigated by limiting the creation of access roads, using sediment control structures and employing selective cutting. The second cause of sedimentation is the laying of pipelines or underground transmission lines across the stream bed. Three techniques are available: trenching across the stream, jacking the pipe through the earth below the stream bed, or aerial crossings. For large pipelines and wide streams, the second method borders on tunneling and may be prohibitively expensive. It is therefore not often used, although it is generally less disruptive to the stream bed.

The method most commonly used is the first: burying the pipe in the stream bed, either by using temporary cofferdams or by traveling directly across the stream. The effects of these actions depend on several factors, including the type of bottom, the streamflow, its quality and the time of year during which the construction occurs. A stream bed consisting of clean coarse sands and gravels presents few problems. Any sediments disturbed during trenching will rapidly resettle without causing excessive turbidity problems. As the bed composition grades into finer materials, turbidity associated with trenching increases due to the decreased settling velocities of the smaller particles. Disturbance of sediments rich in finely divided organic muds can also cause depletions in the amount of dissolved oxygen available to aquatic life.

Streams flowing over bedrock or with rocky bottoms, on the other hand, present special problems, as they cannot easily be trenched. Streams in this state are commonly young, relatively steep, narrow and swift. They are still in the eroding, channel-cutting phase and have not yet begun to deposit sediments. Older streams may have rock bottoms along short reaches, but generally have thick deposits of sediment along adjacent reaches. The smallest streams may be temporarily dammed or diverted while trenches are blasted, or a tunnel for the pipe may be drilled below the bed. Again, the second method would have fewer effects on the aquatic life, but would be more difficult and expensive. In many cases, a trench is constructed by blasting directly in the stream. This method is potentially quite disrupting to stream life due to the shock wave caused by the explosions.

Occasionally, circumstances will be such that an aerial crossing will be used. This usally occurs when a stream is bedded in hard rocks or has worn a deep narrow canyon. Slurry pipelines also tend to use aerial crossings over steep stream valleys because of their slope limitations. Aerial crossings have a minimal impact on water quality and stream biota, although they are generally more expensive and may have a significant visual impact.

Streamflow at a point where a pipe is laid across the stream also affects the resultant turbidity. A rapid stream will tend to disperse disturbed sediments more easily than a slow-moving stream. Another consideration is the existing water quality. Naturally turbid streams tend to be less significantly degraded from the material stirred up by trenching. However, the effect on water biota should be considered, as these frequently have a specific range of turbidity that they can tolerate.

The flow velocity of a stream downslope from a construction area affects the magnitude and extent of the turbidity caused by on-site erosion. A rapid stream will tend to dilute the added sediments, causing the water to be less turbid, although the effect will be distributed over a longer segment of the stream than would be the case for a slow-moving or static system.

An additional factor affecting the amount of harm caused by construction is the season of activity. During winter, when the water has greater density because it is colder, the solubility of oxygen is higher and aquatic life is less active. These effects are more extreme in northern latitudes, but also occur in the South. Although sediment settles more slowly in dense water, the effect on aquatic life is not as great. Since there is more dissolved oxygen available, a larger oxygen demand by the sediments can be tolerated. Where the ground is frequently frozen and much of the local precipitation occurs as snow, there will be less sediment immediately eroded from exposed areas. However, revegetation does not occur until spring, so it is necessary to plan adequate control measures. The advantage is that work may proceed with little chance of damage during operations, allowing control methods to be implemented as a total system after completion of the construction activity.

None of the factors in the preceding discussion is absolute. There is no definite cutoff point at which it is no longer advisable to trench through a stream. Measures that may be helpful in making the decision include a particle size distribution curve of the bottom sediments, the cross-sectional areas and discharge in cubic feet per second (cfs) of the stream, its average turbidity, and, perhaps, suspended solids concentration in milligrams per liter (mg/l). Turbidity is commonly measured in Jackson Turbidity Units (JTU), a measure related to the ability of light to pass through a solution. Preferably, these readings should be taken at several points along the length of the stream. These factors can be combined into a qualitative measure indicating the impact expected from trenching the stream bed. For example, a stream with initially low turbidity, low to moderate flow, a silty bottom and abundant aquatic life would be severely affected, while a stream with low to moderate flow and a clean sand bottom, or a highly turbid stream, devoid of sensitive aquatic life, would be only slightly affected.

Much of the data needed to assess the expected impact of trenching through a stream will be available in documentary form from past records of routine samplings. The U.S. Army Corps of Engineers, the Environmental Protection Agency, the U.S. Geologic Survey, regional Water Basin Commissions, State Engineers' Offices and Water Quality Boards are likely sources, as are previous environmental impact statements of projects in the specific area of concern. In most instances, such records are likely to be sufficient and will obviate the need for devoting a number of man-days to a set of field tests and measurements. In this connection, it should be noted that in many areas of the country, rivers and smaller streams are annually subject to heavy runoff during specific periods. During these periods, sedimentation and turbidity can be produced such that the effects of constructing utility lines, by contrast, are inconsequential.

Waters also present a corrosion hazard to pipelines and cables that require special protective measures. Just as rocks are subject to weathering and erosion, pipes are subject to corrosion. This is a continuous natural process that can never be completely stopped. However, its rate depends on local chemical conditions and can vary significantly from place to place. For further discussion of this effect, see the section below on Water Quality.

Groundwaters

There are two ways that the construction and operation of a utility corridor may impact on groundwater. During construction, sediment-laden runoff can plug the pore spaces in the soils of an aquifer recharge area. This would inhibit the flow of water into the groundwater supply and subsequently lower the water table in that area. In addition, since less water would enter the ground, runoff would increase and possibly cause greater erosion in the recharge area. The first factors that should be considered are the types of aquifers present and the location of their recharge areas.

An artesian aquifer is an aquifer confined between two impermeable strata through which water flows under pressure. Recharge areas for artesian aquifers are usually quite small compared to the extent of the aquifer and are located at the elevation at which the confining strata intersects the ground surface or another permeable formation. Needless to say, if the recharge area is downslope from a construction area, it is in danger of being plugged. The entire ground surface functions as a recharge area for an unconfined aquifer so that although plugging may be a problem, it is not usually as severe as in the case of an artesian aquifer.

Other factors that should be determined are the particle size and sorting of the soils in the recharge area. Particle size and sorting gives an indication of the magnitude of the pore spaces. Coarse, well sorted (narrow size distribution, relatively consisent) sands have large void spaces that are not easily plugged except by large amounts of silt and other eroded materials. Poorly sorted soils have smaller pores because the interstices between the large particles are filled with smaller particles. Since the void spaces are smaller, they are much more likely to be filled by materials eroded from uphill construction sites.

The second way a corridor affects groundwater primarily concerns pipelines. Trenching and pipelaying often necessitate extensive dewatering, especially in areas with an originally high water table. In the special case of slurry pipelines, large amounts of water are needed to form the slurry. This water is frequently obtained from the groundwater and can amount to 15,000 acre-feet per year. Such dewatering can have various effects, depending on the type of soils, the extent of dewatering and whether or not the groundwater system is tapped for any other purpose.

Subsidence is a prominent problem in such cases. It has been discussed in the section on pedology. Other effects are concerned with the loss of the pumped water for other purposes and possible increased pumping costs for other users due to a lower water table. Factors that should be considered include total water storage capacity, its variation through the year, magnitude of other local withdrawal and the aquifer recharge rate. These can be measured in acre-feet and used to perform a water balance for the system. The extent of the area affected may be determined by equations in Todd (1967) or other hydrology texts. The area of influence depends largely on the permeability of the aquifer. Permeability can be measured in gallons per day per square foot (gpd/ft^2), a good aquifer being greater than approximately 25 gpd/ft^2 and ranging to 10^6 gpd/ft^2. The affected area will be large for a highly permeable soil, although the magnitude of the drawdown will be less severe since it will be spread over a wider area.

Groundwater quality is an important factor in determining the demand for the use of that water in future developments as well as its usefulness in a slurry. Obviously, low quality water will be in less demand and can therefore be used without conflict. On the other hand, low quality water might increase the corrosion potential of a pipeline and be undesirable in a slurry.

Groundwater conditions can also affect pipelines or buried conductors. The process of corrosion has already been discussed in the sections on pedology and surface hydrology. Similar effects occur with groundwater. One corrosion-causing condition not usually associated with surface waters is that of an organic rich, anaerobic ($E_H < 0$) environment of 5.5 to 8.0 pH, such as found in many swamplands. Sulfate-reducing bacteria that thrive under these conditions use metallic iron as an electron source and produce $Fe(OH)_2$ and FeS at the expense of unprotected pipes.

WATER QUALITY

The water quality of area streams and lakes both affects and is affected by corridor location. Pipelines or buried power lines are affected by the corrosive potential of the waters, which increases the requirements for protection. Important parameters that could potentially cause corrosion problems for pipelines include high total dissolved solids content and high values of electrical conductivity. Total dissolved solids (TDS) is a measure of salinity or the concentration of ionized salts in a water body. TDS is usually measured in milligrams per liter (mg/l). The presence of large numbers of ions in solution can create an electrochemical reaction in which the metal of an unprotected pipe will ionize and react with the solution. Waters containing more than 300 mg/l TDS generally require protective measures.

Electrical conductivity is the measure of the degree of mineralization and activity of the electrically charged ions in the water. Its units in natural environments are micromhos (μmhos), with natural values in the approximate range 30 to 4000. Values in excess of 1000 μmhos are generally considered corrosive to unprotected metals, although protection is recommended at much lower values as well.

Other factors that indicate corrosion potential are oxidation-reduction (redox) potential and pH. The redox potential is commonly called Eh and is measured in volts. It measures the ability of a natural environment to oxidize a given element or compound or to bring about any other oxidation or reduction process. Most natural environments occur in the range between -4 (anaerobic) and +.8 (oxygen rich), although extreme cases are known to exist. Hydrogen ion activity, conveniently expressed as pH, is another factor influencing corrosion. Acidic conditions (hydrogen ion activity 10^{-4} or $pH < 4$) in the presence of oxygen ($E_H > .3$) favor corrosion of most metals.

Other conditions affecting the corrosiveness of a solution are the types of ions present. A hard water (rich in calcium and carbonates) will inhibit corrosion due to the formation of a protective film of $CaCo_3$. Other special corrosion-inducing factors exist. However, corrosion protection devices are presently in common use and a detailed analysis of corrosion is beyond the scope of this report. Detailed discussions of corrosion may be found in Uhlig (1970).

As regards the effect of corridors on water systems, an important factor is the original condition of a water body. A lake or stream of originally low quality can tolerate a much more severe impact than a previously undisturbed clean water body. This does not mean that there is no need for protection from further degradation for waters that have already been degraded. Such waters may still be returned to a healthy state. However, the potential effect will be more severe on waters with an existing high quality.

Factors of concern include turbidity, suspended and dissolved solids concentrations, temperature and dissolved oxygen. An appropriate measure is that of suspended solids, commonly given in units of mg/l. Total suspended solids (TSS) is a measure of the material being carried by the stream as fine particles. Such material is generally derived from erosion. The EPA Water Quality Criteria (1972) recommends a maximum TSS concentration of 25 mg/l for a high level of protection for aquatic life, 80 mg/l for moderate protection and up to 400 mg/l as a low level of protection.

Dissolved solids are measured in the same units. This measure indicates the concentration of salts leached from rocks and solids as well as dissolved pollutants introduced by man, such as fertilizers or heavy metals. Total dissolved solids (TDS) concentration is not only significant with regard to corrosion, but is an important indicator of overall water quality. TDS concentrations in natural waters range from 50 to 500 mg/l. The EPA (1972) recommends only that "total dissolved solids should not be changed to the extent that biological communities characteristic of particular habitats are significantly changed. Tolerances are to be determined by field studies."

Since many aquatic organisms are quite temperature sensitive, and water temperature can sometimes be affected by clearing activities along shorelines, proper consideration should be made of this factor. Shoreline clearing may destroy the natural shading effect of trees and expose the water to direct sunlight, thereby causing an increase in temperature of cold water systems. This effect might be important in streams and lakes whose ambient temperature is consistently less than atmospheric temperature and whose shores are densely lined with trees. Introduction of highly turbid (high suspended solids) waters also increases water temperature. The turbidity increases the thermal absorption of the surface waters, while preventing sunlight from reaching and warming deeper waters.

Considerations involving dissolved oxygen (DO) are similar to those discussed for turbidity and dissolved solids. DO is measured in mg/l. Oxygen solubility is a function of water temperature. The maximum amount of oxygen that can be dissolved varies from 14.6 mg/l at 32^{o}F to about 9 mg/l at 77^{o}F and less at higher temperatures. The actual concentration in a natural water body depends on the use of oxygen by aquatic life for decomposition of organic matter and oxygen recharge. Oxygen recharge occurs physically by diffusion from the atmosphere and biochemically by photosynthesis carried out by aquatic plants. Diffusion is generally a slow process and the rate decreases with increasing temperature. In productive waters, photosynthesis is an important, although variable, oxygen source. Photosynthesis is dependent on adequate light and, therefore, on water clarity. The reduction of dissolved oxygen as an eventual consequence of erosion is an important potential effect of corridor construction near water bodies. The EPA water quality criteria (1972) recommend a graduated scale for minimum DO, depending on the minimum natural concentrations and on the level of desired protection, with an absolute minimum value of 4 mg/l (see Tables III-9 and III-10). When DO levels sink below minimum levels, not only are there fish kills, but there is a possibility of the formation of odorous gases, such as hydrogen sulfide (H_2S) due to the actions of anaerobic bacteria. Therefore, if the DO of a water body approaches 5 mg/l, any development in that area that could produce erosion should be discouraged.

The foregoing discussion is equally applicable to power lines. In regard to power lines, the problems can be mitigated by proper

TABLE III-9

EXAMPLE OF RECOMMENDED MINIMUM CONCENTRATIONS OF DISSOLVED OXYGEN

ESTIMATED NATURAL SEASONAL MINIMUM CONCENTRATION OF OXYGEN IN WATER (mg/1)	CORRESPONDING TEMPERATURE OF OXYGEN-SATURATED FRESH WATER	RECOMMENDED MINIMUM CONCENTRATIONS OF O_2 FOR SELECTED LEVELS OF PROTECTION (mg/1)			
		NEARLY MAXIMAL	HIGH	MODERATE	LOW
5	(a) (a)	5	4.7	4.2	4.0
6	48C(a) (115F)(a)	6	5.6	4.8	4.0
7	36C (96.8F)	7	6.4	5.3	4.0
8	27.5C (81.5F)	8	7.1	5.8	4.3
9	21C (69.8F)	9	7.7	6.2	4.5
10	16C (60.8F)	10	8.2	6.5	4.6
12	7.7C (45.9F)	12	8.9	6.8	4.8
14	1.5C (34.7F)	14	9.3	6.8	4.9

(a) Included to cover waters that are naturally somewhat deficient in O_2. A saturation value of 5 mg/1 might be found in warm springs or very saline waters. A saturation value of 6 mg/1 would apply to warm sea water (32° C=90°F).

Note: The desired kind and level of protection of a given body of water should first be selected (across head of table). The estimated seasonal minimum concentration of dissolved oxygen under natural conditions should then be determined on the basis of available data, and located in the left-hand column of the table. The recommended minimum concentration of oxygen for the season is taken from the table.

Source: U.S. Environmental Protection Agency, Water Quality Criteria--1972, EPA-R3-73-033, Washington, D.C., 1972.

TABLE III-10

DESIRED TYPE AND LEVEL OF PROTECTION OF FISH AGAINST EFFECTS OF REDUCED OXYGEN CONCENTRATION

LEVEL OF PROTECTION	INTENDED TYPE OF PROTECTION	POSSIBLE APPLICATIONS
Nearly Maximum*	For virtually unimpaired productivity and exchanged quality of a fishery.	Appropriate for conservation areas, parks, and water bodies of high or unique value. Requires, practically speaking, that little or no deoxygenating wastes be added to natural waters. Nor must there be any activities such as unfavorable land use which would reduce O_2 levels.
High	Not likely to cause appreciable change in the ecosystem, nor material reduction of fish production. Some impairment is risked, but appreciable damage is not to be expected at these levels of oxygen.	Could be appropriate for fisheries or aquatic ecosystems of some importance, which should not be impaired by other uses of water.
Moderate	Fisheries should persist, usually with no serious impairment, but with some decrease in production.	Could be used for fisheries which are valued, but must co-exist with major industries or dense human population.
Low	Should permit the persistence of sizeable populations of tolerant species and successful passage of most migrants**. Much reduced production or elimination of sensitive fish is likely.	Appropriate for fisheries that have some commercial or recreational value, but are so unimportant compared with other water uses, that their maintenance cannot be a major objective of pollution control. This type of protection should, however, provide for survival of sensitive species in adult or subadult life stages for short periods during the year, if oxygen levels at other times are satisfactory for growth, reproduction, etc.

[*] Note that there could be a higher level of protection that would require oxygen to be near natural level at all times whereas nearly maximum requires only that oxygen should not fall below the lowest level characteristic of the season.

[**] But will not protect migrating salmonids, which would require at least a moderate level of protection for zones of passage.

Source: U.S. Environmental Protection Agency, Water Quality Criteria--1972, EPA-R3-73-033, Washington, D.C., 1972.

placement of towers and selective cutting techniques. In some instances they can be entirely obviated by spanning the crossing so as to avoid disturbing the water. Solutions are not that simple for pipelines. In addition to requiring complete clearing of the ROW, the pipes have to be laid directly in the stream bed. Trenching through the stream unavoidably causes the resuspension of bottom sediments and subsequent, if only temporary, stream turbidities. If these bottom sediments contain any noxious elements that have accumulated slowly through time, their disruption could be harmful.

A related problem is that of stream channelization during trenching. Any change in streamflow or cross-section can change the flow velocity and erosion patterns downstream. This can lead to problems resulting in increased turbidity and reduced DO levels. Therefore, any crossings requiring channelization should be carefully considered.

Consultation with local authorities is useful. Table III-11 lists the agencies for selected states concerned with water quality control. These sources will often have past water quality data for many of the waters of their states. They will also be able to supply the state water quality regulations and standards for various uses.

METEOROLOGICAL CONDITIONS

Except in extreme cases, climate is not a useful corridor routing determinant since weather patterns are usually approximately constant over wide areas. Exceptions include very long lines that may be routed to avoid areas of harsh or unfavorable climate (particularly strong winds and heavy ice) and mountainous areas where local climate depends on altitude and can vary markedly between a mountain peak and an adjacent valley.

Even though climate has a minimal effect on corridor location, it is still quite important in determining design criteria for a line in order to maximize its reliability and minimize environmental damage. There are general areas in which climate interacts with utilities to affect the potential impact of transmission and delivery facilities. Wind, ice, corona effects, and lightning are important for power lines; erosion is an important consideration for all construction activities.

Wind and Ice

A coating of ice imposes an abnormal vertical load on overhead transmission lines by which conductor tension increases directly with the added weight. The increase may be four or five times normal weight. For example, ice to a radial thickness of one-half inch increases the weight of six No. 6 copper wires 100 feet long from 67 to about 370 pounds. The additional stress on the conductors is communicated through

TABLE III-11

STATE WATER QUALITY AGENCIES

Arizona

Department of Health
Division of Water Quality Control
1740 West Adams
Phoenix, AZ 85007

California

Water Resources Control Board
1416 Ninth Street
Sacramento, CA 95814

Colorado

Department of Health
Water Pollution Control Division/
Commission
4210 East 11th Avenue
Denver, CO 80220

Idaho

Department of Environmental and
Community Services
Environmental Services, Air and
Water Programs
State House
Boise, ID 83720

Montana

Department of Health and Environmental Sciences
Environmental Sciences Division,
Water Quality Bureau
Helena, MT 59601

Nevada

Bureau of Environmental Health
Water Quality Office
201 South Fall Street
Carson City, NV 89701

New Mexico

Environmental Improvement Agency
Water Quality Section
P. O. Box 2348
Santa Fe, NM 85701

North Dakota

Department of Health
Division of Environmental Engineering
Water Supply and Pollution Control
Bismarck, ND 58501

Oregon

Department of Environmental Quality
Water Quality Control Division
1400 S. W. Fifth Avenue
Portland, OR 97201

Utah

Division of Health
Bureau of Environmental Health
44 Medical Drive
Salt Lake City, UT 84113

Washington

Department of Ecology
Public Services Branch, Water
Investigations Division
Olympia, WA 98501

Wyoming

Department of Environmental
Quality
State Office Building
Cheyenne, WY 82002

them to poles and towers. The load imposed by winter icing is affected by the prevailing winds during the icy season. The ice coating greatly increases the area of conductors exposed to wind. Increased loading due to wind pressure can be significant in any event where winds frequently reach a velocity of 40 miles per hour or greater. The forces are strongest from a wind at right angles to the direction of the wires. Therefore, direction of prevailing winds can be an important consideration in determining the exact placement of an overhead transmission line, particularly in latitudes or altitudes where icing is regularly experienced (Handbook for Electrical Engineers, 1968).

Corona

Corona can be defined as an electrical discharge that occurs when the voltage applied to a conductor is greater than the dielectric strength of the surrounding insulation. For high voltage overhead transmission lines, corona is produced when the dielectric of the air is exceeded. This ionizes the air and ozone and nitrous oxides are formed. Corona appears as bluish tufts or streamers surrounding the conductor. A hissing sound can usually be heard nearby. An ozone odor may be apparent when corona activity is intense. Electrical interference from corona activity can degrade radio and television reception.

Small protrusions or irregularities on conductors and supporting hardware will normally exist and become a corona source at lower voltages than the general corona onset voltage of the line. These irregularities may consist of bugs, bird droppings, dust, dew, snow, water droplets, or burrs and nicks on the conductor. Since any corona activity involves a power loss, it is standard engineering practice to design for essentially zero corona during normal operating conditions (U.S. Department of the Interior, Bonneville Power Administration, 1975).

Corona effects vary strongly with atmospheric conditions. Humidity is one of the most important factors, with conditions in excess of 79 percent humidity favoring corona formation. Corona is also influenced by precipitation. Intensity and duration of rainfall and snowfall are important factors for which data are available to provide an indication of the potential magnitude of the corona effect. Intense rainstorms or other foul weather conditions cause large coronas. Although audible noise projection is greatest during heavy rainstorms, background noise from the rain masks the effects of electrical noise. Therefore, fog is considered the condition that causes the worst noise emission.

Concern that has been expressed over the creation of ozone and nitrogen oxides by corona effects from transmission lines appears to be unfounded. Intensive studies have shown that no measurable amounts of these gases occur at ground level in the vicinity of transmission lines up to 765 kV (Frydman *et al.*, 1972).

Lightning

Lightning strikes are important considerations in areas where intense thunderstorms are common. Lightning ionizes air molecules and can cause power surges in the conductor and (even more likely) can create conditions that short the conductors with each other and with ground, causing system failures. One measure of lightning frequency is the number of strikes to ground per square mile per year. Since this lightning frequency is difficult to measure, it is often approximated based on the number of thunderstorm days per year. Figure III-10 is an isokeraunic (thunderstorm frequency) map that shows these data for the United States. It has been reported that a number of cloud-to-ground lightning strikes per square mile averages 0.33 times the number of thunderstorm days per year (Westinghouse, 1973). The probability of a structure being hit increases with its height and, hence, with the voltage of the power line. Table III-12 shows the probable number of lightning strikes vs. height of structure estimated for an area subject to 25 to 40 thunderstorms per year. The study area may be divided into lightning density zones based on observed data and alternate routes may be compared on the basis of the number of lightning strikes per year per route.

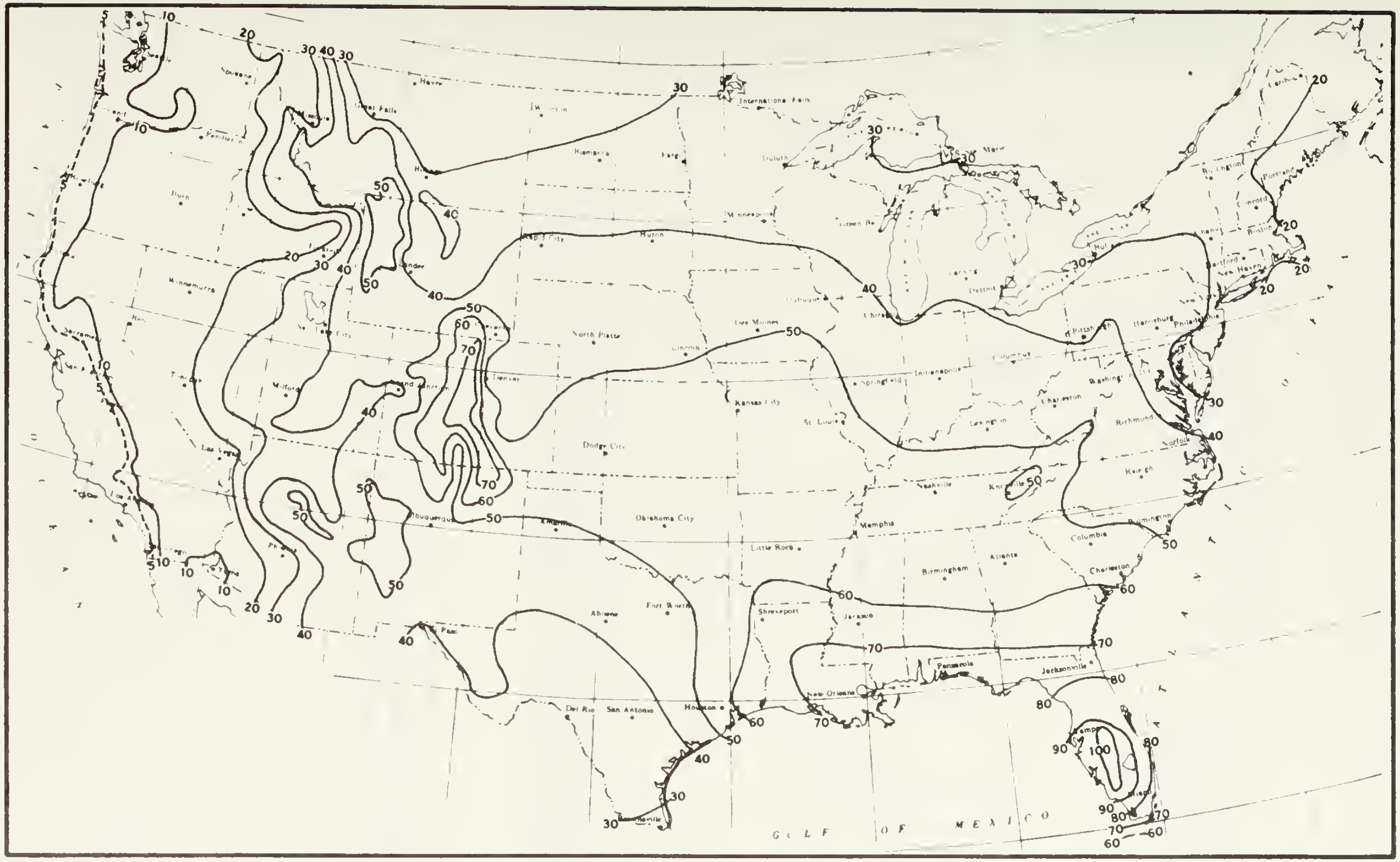
General Considerations

Another way in which weather affects the reliability of a power line is through deterioration of the insulation material. Areas subject to temperature extremes, heavy ice loadings and strong winds tend to break down insulation, reducing its effectiveness and increasing corona and arcing effects. Extremely dusty areas lead to insulator fouling and increased leakage. Thermal expansion, stretching due to ice and wind loads, and brittle cold conditions can lead to conductor fatigue. Each of these climatic effects should be taken into consideration when selecting an area for routing power lines.

Slurry pipelines have an additional restriction. Since the cheapest and, therefore, most common transport fluid is water, the pipe must be buried at a depth below the soil frost line to prevent freezing.

Influence on Erosion

Climate influences erosion. Rainfall intensity is one of the factors of the Universal Soil Loss Equation (see section on Pedology). It has been determined to be the driving force in waterborne overland erosion. Iso-erodant maps have been prepared by Wischmier and Smith (1965) and expanded by the EPA (1973) (Figure III-3). It has been found that the maximum 30-minute rainfall intensity correlates well with the soil loss R factor as an indicator of erosion potential (see Figure III-4).



Source: U.S. Department of Commerce, Environmental Science Services Administration, Selected Climatic Maps of the United States, 1966.

FIGURE III-10

MEAN ANNUAL NUMBER OF DAYS WITH THUNDERSTORMS

TABLE III-12

PROBABLE LIGHTNING STRIKES PER YEAR VS. STRUCTURE HEIGHT, GIVEN 25-40 THUNDERSTORMS PER YEAR

STRUCTURE HEIGHT (feet)	EXPECTED NO. OF STRIKES
300	1
*600	3
800	5
1000	10
1200	20

Source: Westinghouse Environmental Systems, Colstrip Generation and Transmission Project, Applicant's Environmental Analysis, November 1973.

*Note that values for structure heights greater than 600 feet are of theoretical interest only, since there are few if any transmission towers exceeding this height.

Rainfall also helps determine the length of time a construction site will remain exposed. Areas of high rainfall may be subject to large amounts of erosion, but the impact is felt for only a short period of time, as vegetation should quickly reestablish itself on the denuded area, providing that proper control measures are taken.

Wind erosion also occurs, especially in dry areas with large areas of unconsolidated soils. Deserts and other semi-arid regions are prime candidates for this process. The so-called "Badlands" of Montana and the Dakotas is an example of an area especially susceptible to wind erosion.

AIR QUALITY

Construction and maintenance operations for both power lines and pipelines will contribute air pollutants just as do any construction activities. The primary pollutants are fugitive dust raised by moving vehicles and exhaust from construction equipment and motor vehicles. The magnitude of these sources depends on the length of the line, the method of construction, the type of terrain, and the type of dust control measures that are used. In extremely rugged or unusual terrain, more equipment may be required to construct a given length of line. Sometimes helicopters are used instead of trucks. Other potential sources of air pollution during construction include dust from blasting and smoke, if vegetation cleared from the right-of-way is burned. The emissions from construction and maintenance vehicles and equipment should be estimated and their expected impact on air quality calculated, using standard models such as those given in the HEW Workbook of Atmospheric Dispersion Estimates (Turner, 1969). Average factors for calculating emission rates may be found in the Environmental Protection Agency's "Compilation of Air Pollutant Emission Factors," which is updated periodically.

After the lines are in place, except for exhaust from maintenance vehicles, the only sources of air pollution from pipelines are the compressor stations, which contribute exhaust principally in the form of small amounts of nitrogen dioxide, hydrocarbons and carbon monoxide. Expected emissions should be calculated and their impact on local air quality conditions assessed. In addition, an analysis should be done of the probability of gas pollutant leakage from a pipeline.

As noted above, air pollution associated with corona effects from operating power lines, specifically the generation of ozone and nitrogen oxides (NO_x), can be discounted. This point should be specifically noted because of the extent to which it has been an issue of concern. Laboratory and field studies performed by the American Electric Power Service Corporation and the Battelle Memorial Institute in 1970 and 1971 (Frydman _et al._, 1972) under and in the vicinity of an energized

765 kV line indicated that no perceptible amounts of ozone (only 2 to 3 parts per billion) were being generated by the power line. During these studies, ambient levels, as measured 45 to 1105 meters upwind from the line, varied from 12 to 64 parts per billion (ppb). The EPA air quality standards limit ozone concentration to 80 ppb, not to be exceeded more often than one hour per year.

Nitrogen oxide production rates were determined in the same studies to be of the same order of magnitude as ozone. EPA standards for NO_x list a maximum annual average concentration of 53 ppb. According to the results of these studies, which involved extensive monitoring of actual transmission lines, ozone is not a pollution problem from power lines up to 765 kV even in foul weather when conditions contributing to maximum production occur. The researchers recommend, however, further work on lines of higher voltage that are now coming into use.

In assessing the potential impact of transmission lines, the applicant can, as a precautionary measure, calculate the expected ozone concentration. For example, this was done, in the _Draft Environmental Statement for the Byron Station_ in Illinois using the methodology of the studies referred to above (U.S. Atomic Energy Commission, Directorate of Licensing, 1974). It was calculated that the 765 kV line involved would generate ozone at about 0.68 lb/mile/hr in foul weather and about 0.015 lb/mile/hr in fair weather. The corresponding steady-state concentration for uniformly dispersed ozone around the line within a volume of air 10 miles by 1 mile by 100 meters would range from 0.05 to 0.5 ppb and 0.001 to 0.01 ppb, depending on wind conditions. Roach _et al._ (1973) also give a method for estimating ozone concentrations. Table III-13 lists the state agencies that may be contacted for current state air quality regulations.

TABLE III-13

STATE AIR QUALITY AGENCIES

Arizona

Department of Health
Division of Air Pollution Control
1740 West Adams
Phoenix, AZ 85007

California

Air Resources Board
1025 "P" Street
Sacramento, CA 95818

Colorado

Department of Health
Air Pollution Control Division/
Commission
4210 East 11th Avenue
Denver, CO 80220

Idaho

Department of Environmental and
Community Services
Air and Water Programs
State House
Boise, ID 83720

Montana

Department of Health and
Environmental Sciences
Environmental Sciences Division
Helena, MT 59601

Nevada

Bureau of Environmental Health
Air Quality Office
201 South Fall Street
Carson City, NV 89701

New Mexico

Environmental Improvement Agency
Air Quality Section
P. O. Box 2348
Santa Fe, NM 87501

North Dakota

Department of Health
Division of Environmental
Engineering
Air Pollution Control Program
Bismarck, ND 58501

Oregon

Department of Environmental Quality
Air Quality Control Division
1400 S.W. Fifth Avenue
Portland, OR 97201

Utah

Division of Health
Air Quality Section
44 Medical Drive
Salt Lake City, UT 84113

Washington

Department of Ecology
Public Services Branch, Air
Resources Division
Olympia, WA 98501

Wyoming

Department of Environmental Quality
State Office Building
Cheyenne, WY 82002

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Page, R., D. Boore, W. Joyner and H. Coulter, 1972. Ground Motion Values for Use in the Seismic Design of the Trans-Alaska Pipeline System, U.S. Geological Survey Circular No. 672, Washington, D. C.

Roach, J., V. Chartier and F. Dietrich, 1973. "Experimental Oxidant Production Rates for EHV Transmission Lines and Theoretical Estimates of Ozone Concentrations Near Operating Lines," IEEE Transactions Paper. T-73-414-0.

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Turner, D. Bruce, 1969. Workbook of Atmospheric Dispersion Estimates, U.S. Department of Health, Education and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Cincinatti, Ohio.

Uhlig, H.H., 1971. Corrosion and Corrion Control, John Wiley & Sons, New York.

U.S. Atomic Energy Commission, 1974. Draft Environmental Statement Related to the Proposed Byron Station Units 1 and 2 of the Commonwealth Edison Company, Washington, D.C.

U.S. Department of Agriculture, Soil Conservation Service, 1971. Guide for Interpreting Engineering Uses of Soils, with modifications.

U.S. Department of Commerce, Environmental Science Services Administration, 1966. Selected Climatic Maps of the United States.

U.S. Department of the Interior, Bonneville Power Administration, 1975. Personal Communication, May.

U.S. Department of the Interior, Bureau of Land Management, 1974. WSO 2800-22b, November.

U.S. Department of the Interior, Geologic Survey, 1970. National Atlas of the United States of America, Washington, D.C.

U.S. Environmental Protection Agency, 1972. Water Quality Criteria--1972 EPA-R3-73-033, Washington, D.C.

U.S. Environmental Protection Agency, Office of Water Program Operations, 1973. Comparative Costs of Erosion and Sediment Control, Construction Activities EPA-430/9-73-016, Washington, D.C.

Westinghouse Environmental Systems, 1973. Colstrip Generation and Transmission Project, Applicant's Environmental Analysis, November.

Wischmeier, W. H., C. B. Johnson and B.V. Cross, 1971. "A Soil Erodibility Nomograph for Farmland and Construction Sites," Journal of Soil and Water Conservation 26(5):189-193.

Wischmeier, W.H., and D. Smith, 1965. Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains, Agricultural Handbook No. 282, U.S. Department of Agriculture, Agricultural Research Service, Washington, D.C.

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SECTION IV

ECOLOGIC AND BIOLOGIC FACTORS

OVERVIEW

This section deals with the considerations involved in assessing the various impacts that a utility line may have on ecological systems and on the forms of life that comprise them.

Some overlap with the factors considered in Sections III and IV is inevitable, because both involve physical characteristics of the existing environment. Aquatic organisms are directly dependent on water quality, which is strongly affected by any erosion caused by utility line construction; the rate of erosion, in turn, depends on conditions of soil, terrain, and meteorologic and topographic factors presented in Section III. Classification of areas characterized by the presence of particular species of wildlife and vegetation according to biotic provinces reflects, to a considerable degree, some of the physical characteristics that determined the physiographic provinces discussed under Natural Physical Factors. The approach and emphasis of the two sections, however, are quite different. This section is concerned with how environmental factors may interact with features of a utility line to impact on living creatures. This section also considers possible ways to measure or otherwise gauge these variables and the role they may play in comparing alternative locations for utility lines.

After presenting one possible classification of the region of primary interest in terms of biotic provinces, the potential impacts and relevant factors are presented in two major subsections: Terrestrial Ecology and Aquatic Biota. The subsection on Terrestrial Ecology discusses the following principal concepts:

- Ecologic systems
- Vegetation/land cover
- Diversity - number and type of wildlife and vegetative species
- Species importance
- Rare and endangered species
- Sensitivity or stability of ecosystems
- Possible means of mitigating adverse impacts

The subsection on Aquatic Biota emphasizes the effect that changes in the water quality resulting from a utility line may have on organisms in an affected body of water, particularly:

- Turbidity
- Suspended and dissolved solids
- Temperature
- Dissolved oxygen

BIOTIC PROVINCES

The North American continent can be divided into a number of biotic provinces, each covering a continuous area of considerable extent and characterized by specific features of physiography, soil, climate, flora, and fauna. Although the boundaries between biotic divisions are hard to fix precisely and one province often tends to merge into another, each is more or less distinct in terms of environmental factors and the life forms that populate it. Within a biotic province, further subdivisions are recognized, such as biotic districts and the life belts that occur only under particular conditions of latitude, altitude and slope (Dice, 1943).

East of the 100th meridian, the United States is covered by only five biotic provinces, but in the West, physical conditions give rise to a great many more. The 11 westernmost states embrace all or parts of no less than 13 biotic provinces (Figure IV-1). The principal characteristics of these provinces are summarized in Table IV-1).

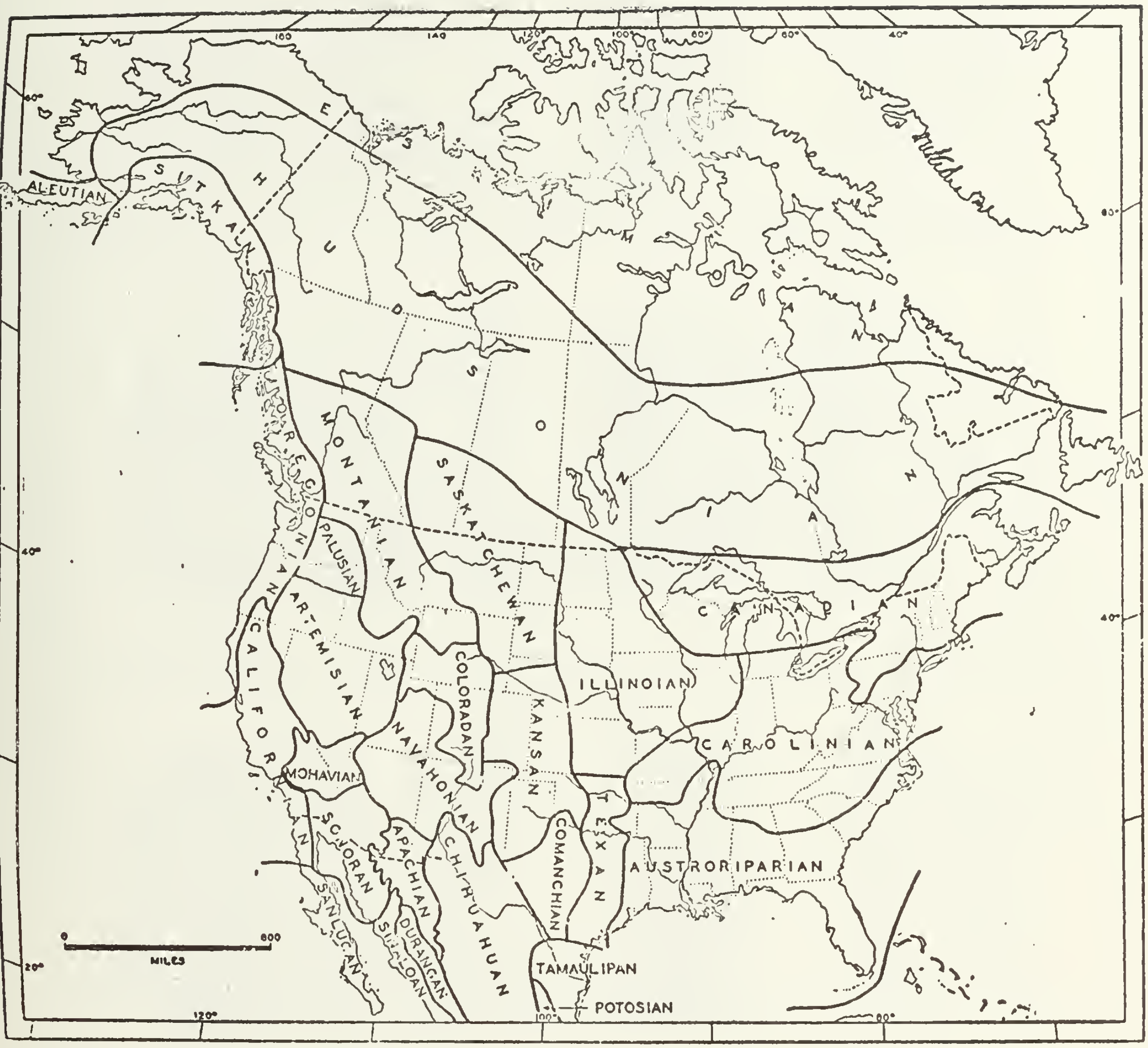
The importance of biotic provinces to assessment of environmental impact is in the fact that the environmental complex of a province is sufficiently uniform so that a characteristic ecology develops. Thus, the important general features that determine and characterize the biological environment of a specific location through which a proposed utility line will pass can be determined by reference to the biotic province in which the location is situated.

The classification of biotic provinces as contrived by Dice is only one of several applicable to the regions comprised within the 11 westernmost states. With its accompanying map, it is convenient for this report because of the detailed breakdown it provides, compared with the more general groupings of many calssifications. Another useful classification system is Aldrich's division into life areas (Figure IV-2). Table IV-2 shows the correspondence of Dice's biotic provinces to other systems by which the regions involved may be characterized.

TERRESTRIAL ECOLOGY

Ecologic Systems

The life of any given region is frequently considered under the two headings of flora and fauna, corresponding to the basic division of biology into botany and zoology. It is frequently convenient in an environmental assessment to consider separately the potential impacts



Source: Dice, Lee R., The Biotic Provinces of North America, University of Michigan Press, Ann Arbor, Michigan, 1943

FIGURE IV-1

THE BIOTIC PROVINCES OF PART OF NORTH AMERICA

TABLE IV-1

CHARACTERISTICS OF BIOTIC PROVINCES

PROVINCE	PREDOMINANT PHYSICAL CHARACTERISTICS	TYPICAL FLORA	NOTEWORTHY FAUNA
Saskatchewan	Semi-arid plains; gently rolling; nearly flat areas; canyons, badlands, buttes, a few mountains	Short grasses dominant; mid-height grasses overgrazed but still present; few trees, except western yellow pine on mountains	Black-footed ferret, kit fox, prairie dog, pocket mouse, pocket gopher, Hayden vole
Kansan	Semi-arid, notably flat, occasional valleys, canyons and buttes; high evaporation rate; long, hot summers	Short grasses dominant as result of overgrazing of mid-height grasses; blue grama, buffalo grass, needle-and-thread grass, bluestem sagebrush in west; cottonwood along rivers	Similar to Saskatchewan plus spotted skunk, harvest mouse, wood rat, sand squirrel, black-tailed jack rabbit
Montanian	Northern Rocky Mountains--rugged; severe winters; little precipitation other than heavy snows	Pines: white bark, western yellow, lodgepole; Firs: alpine, lowland white; Sagebrush; grass; hemlock; western red cedar; western larch; Engelmann spruce	Similar to Cascade Mountains of Oregonian Province. Includes Columbian ground squirrel, Rocky Mountain goat, northern chickaree
Coloradan	Central Rocky Mountains; high elevation, steeply mountainous with high plains, mountain parks; moderate precipitation	Similar to Montanian except successions occur at higher altitudes plus white fir, mountain mahogany, scruboaks; pinon-juniper in south	Similar to Montanian without Columbian ground squirrel or Rocky Mountain goat; also with spruce squirrell, tufted-eared squirrel, Mountain cottontail rabbit

Source: Dice, Lee R., The Biotic Provinces of North America, University of Michigan Press, Ann Arbor, 1943.

TABLE IV-1 (Continued)

CHARACTERISTICS OF BIOTIC PROVINCES

PROVINCE	PREDOMINANT PHYSICAL CHARACTERISTICS	TYPICAL FLORA	NOTEWORTHY FAUNA
Navahonian	Pinon-juniper woodland; Colorado Plateaus; mesas and canyons, volcanic mountains, extensive arid plains; cold winters, hot summers; average precipitation 20 inches except in mountains	Pinon and juniper, grasses and herbs, shrubs, oak brush, yellow pine, Douglas fir. At lower elevations: short grass sod, Xeric shrubs, sagebrush, annuals and perennials, cacti and yucca, cottonwoods. In mountains: lodgepole pine, aspen, Engelmann spruce, alpine fir, bristle cone pine	Yuma clapper rail, Kaibab squirrel, black-footed ferret, Gould's turkey, zone-tailed hawk - All classified among rare, endangered or peripheral species.
Palusian	Plains and mountains; high rolling hills, deep river canyons; hot dry summers, cool, foggy rainy winters	In the sagebrush belt: bunch grass, sagebrush, rabbit brush Bunchgrass belt: wheat bunch grass Montane belt: lowland white fir, western red cedar, western yellow pine, western larch, Douglas fir	Some ground squirrels; some dormant during summer (estivation)

TABLE IV-1 (Continued)

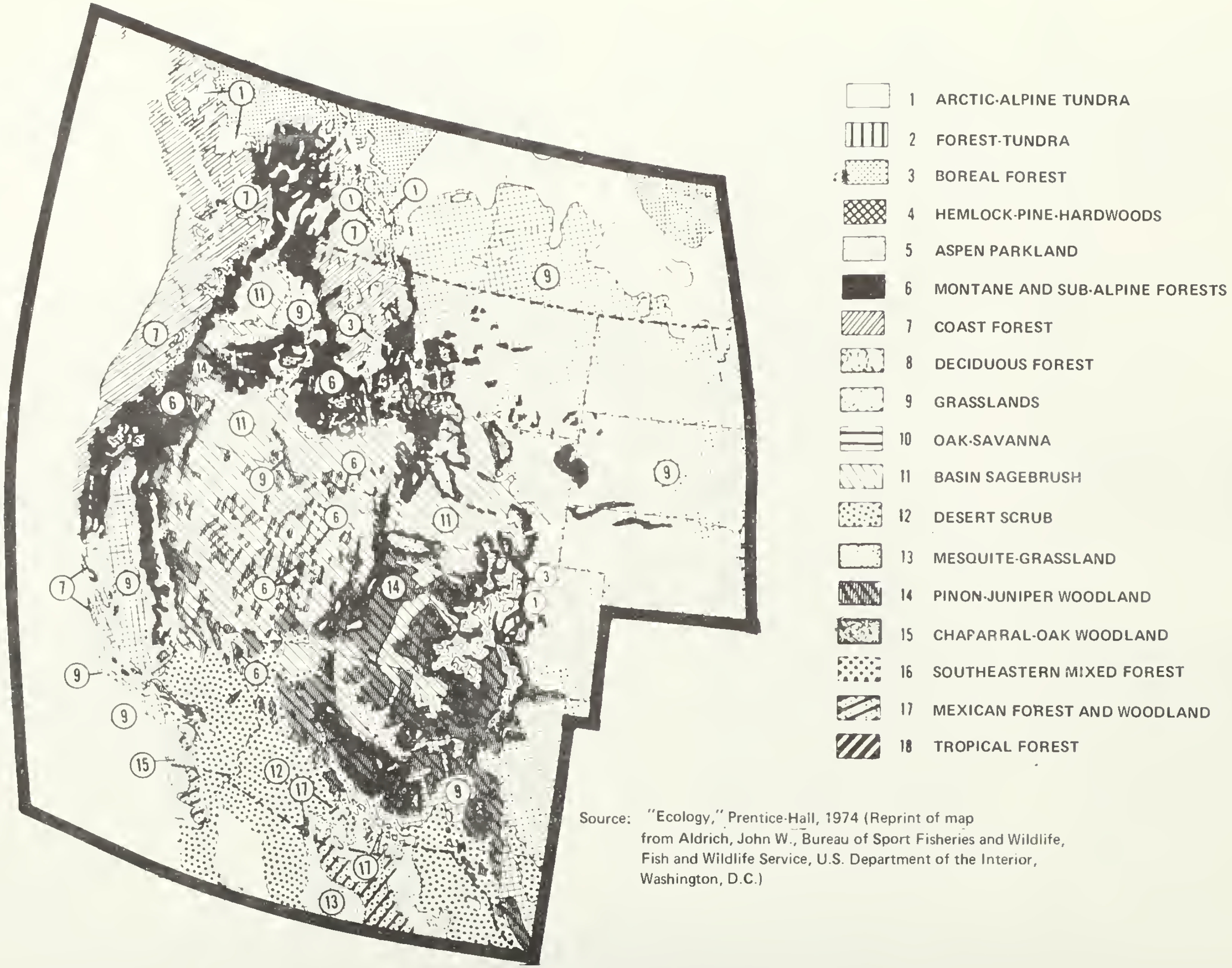
CHARACTERISTICS OF BIOTIC PROVINCES

PROVINCE	PREDOMINANT PHYSICAL CHARACTERISTICS	TYPICAL FLORA	NOTEWORTHY FAUNA
Artemisian	Sagebrush-covered plains, with partly forested mountains; salt flats; semi-arid	Lower life belts: dominated by sagebrush, alkali tolerant shrubs, greasewood, saltgrass, mixed prairie grasses displaced by sagebrush Sabinal belt: similar to Navahonian Montane belt: yellow pine, Douglas fir Subalpine belt: alpine fir, Engelmann spruce	White-tailed antelope squirrel; kangaroo mouse, desert kit fox, desert packrat.
Oregonian	Heavy coniferous forest; humid; mountainous, but also contains narrow coastal plain, volcanic cones	Douglas fir, western red cedar, western hemlock, fir, sitka spruce, Alaska cedar, big leaf maple, Oregon ash, black cottonwood	Shrews, colonial burrowing rodents (*Aplodontia*), Gibb's mole.
Californian	Varied physiography, coast ranges, central valley plains; hot summers with low precipitation	Grassland valley floors; oaks and chaparral in the hills; montane and subalpine flora in the mountains; western yellow pine, Douglas fir, sugar pine, white pine, incense cedar, sequoia	Seasonal migration of many birds and some mammals (mule deer) from North

TABLE IV-1 (Concluded)

CHARACTERISTICS OF BIOTIC PROVINCES

PROVINCE	PREDOMINANT PHYSICAL CHARACTERISTICS	TYPICAL FLORA	NOTEWORTHY FAUNA
Mohavian	Desert valleys, arid; long extremely hot summers; playa lakes; salt flats	Creosote bush, chamiso, shrubs, Joshua trees in northern edges	Yuma clapper rail (described as a threatened species) **lizards, desert animals**
Sonoran	Desert; more rain than Mohavian, though water is still scarce; steep rocky buttes	Sparse stands: cacti, shrubs; creosote bush, mesquite, lechuguilla. On buttes: paloverde, ocotillo sahuaro, brittlebush	Nocturnal burrowing mammals, pocket mice, kangaroo rats, lizards
Apachian	Grassy high plains, many isolated hills and mountains; semi-arid	Desert belt: giant cactus, paloverde, creosote bush Arid grassland belt: short grasses - Bouteloua, mesquite, yucca, cacti Encinal belt: oaks, junipers, shrubs, herbs Montane belt: pines, oaks, Douglas fir, white fir	Lizards, desert kit fox, ringtail, skunks, deer, mice, 40 species of birds.
Chihuahuan	Desert, few permanent streams; isolated mountains; arid but with local torrential summer storms	Shrubs, mesquite, creosote bush, yucca; short grasses to north; bear grass, Spanish bayonet, sotol	Kangaroo rat, lizards



Source: "Ecology," Prentice-Hall, 1974 (Reprint of map from Aldrich, John W., Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.)

FIGURE IV-2
LIFE REGIONS OF PART OF THE UNITED STATES

TABLE IV-2

COMPARISON OF BIOTIC CLASSIFICATIONS

GEOGRAPHIC REGION	ODUM[1]	ALDRICH[2]	DICE[3]	USDA 1957 SOILS BOOK[4]
	Grassland, sage subclimax	Grasslands, basin sagebrush	PALUSIAN	PACIFIC NORTHWEST WHEAT REGION
COASTAL	Moist coniferous forest	Coast forest	OREGONIAN	NORTH PACIFIC
	Coastal chaparral, interior grassland	Chaparral-oak woodland, interior grassland	CALIFORNIAN	DRY MILD-WINTER REGION
DESERT	Creosote bush desert	Desert scrub	SONORIAN	
	Creosote bush desert	Desert scrub	MOHAVIAN	GRAZING-IRRIGATED REGION
INTERIOR	Desert scrub sub-climax Pinon-juniper interior chaparral	Pinon juniper Desert scrub	CHIHUAHUAN	
	Sage-subclimax grassland Pinon-juniper i.c. Grassland	Basin sagebrush Pinon-juniper woodland, grassland	NAVAHONIAN	
	Grassland Pinon-juniper i.c. Coniferous forest Desert-scrub subclimax	Mesquite-grassland Mexican forest and woodland Desert scrub	APACHIAN	
	Sage subclimax Sagebrush grassland Coniferous forest Pinon-juniper i.c.	Basin sagebrush with grasslands Montane and sub-alpine forests Pinon-juniper woodlands	ARTEMISIAN	
	Coniferous forest Coastal-montane forest ecotone Grassland	Boreal forest Coast forest; montane and sub-alpine forests Grassland	MONTANIAN	
	Coniferous forest Pinon-juniper i.c. Sage subclimax grassland	Arctic-alpine tundra Boreal forest Pinon-juniper Basin sagebrush	COLORADAN	
NORTHERN PLAIN STATES	Grassland with isolated coniferous forests	Grasslands with isolated montane and sub-alpine forests	SASKATCHEWAN	NORTHERN GREAT PLAINS
CENTRAL PLAIN STATES	Grassland	Grassland	KANSAN	THE WINTER WHEAT AND GRAZING REGION

1. Odum, E.P., Fundamentals of Ecology, W.B. Saunders Co., 1971 (from map of biomes of North America, p. 380, Figure 14-8, adapted by E.P. Odum from Frank A. Pitelka, 1941).

2. Kendeigh, S.C., Ecology with Special Reference to Animals and Men, Prentice-Hall, 1974 (from map of Life Areas of North America, adapted by John W. Aldrich, Bureau of Sport Fishers and Wildlife, 1966).

3. Dice, L.R., The Biotic Provinces of North America, University of Michigan Press, 1943.

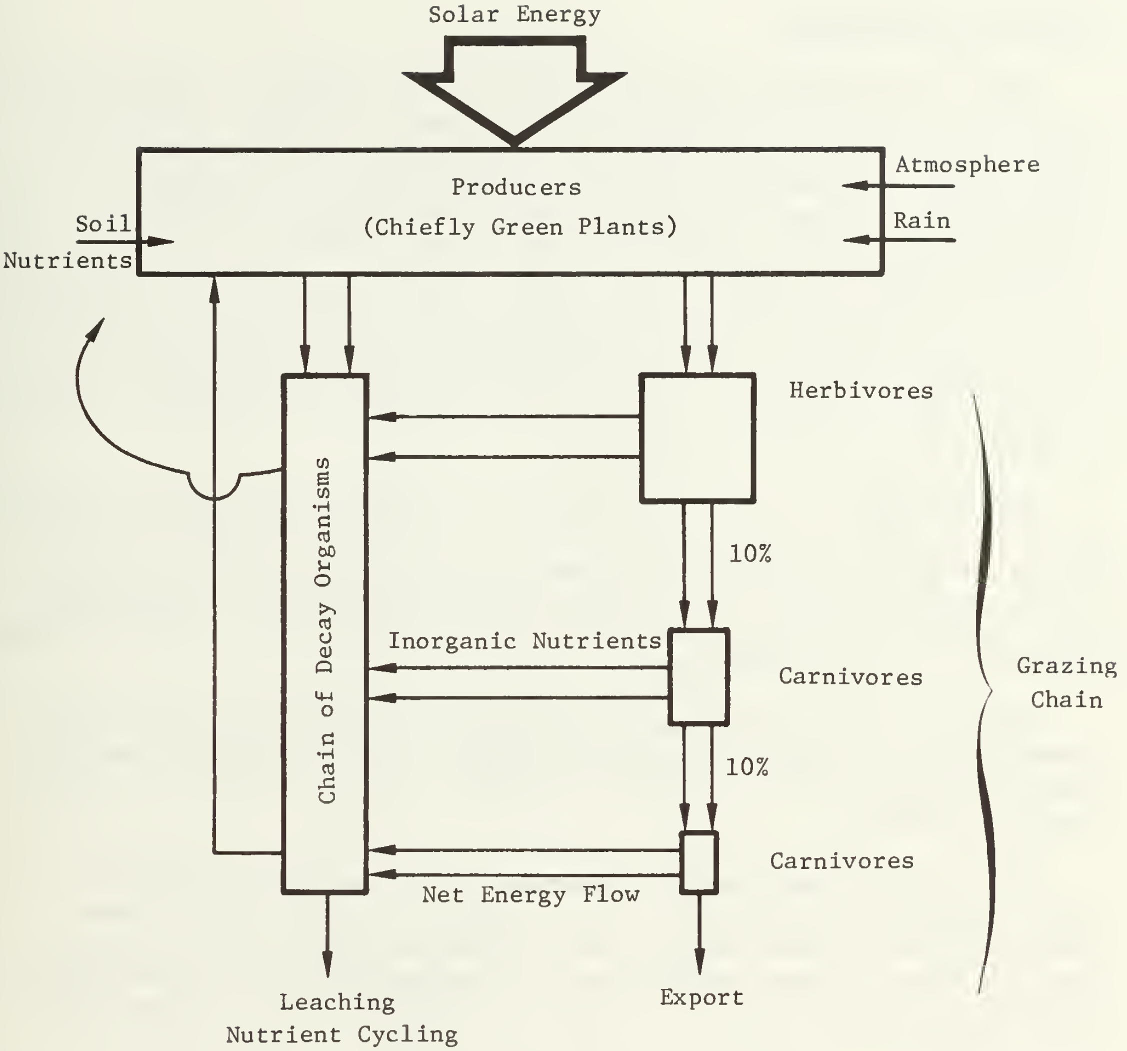
4. Soil, The Yearbook of Agriculture (from regional maps, pp. 456-515, U.S. Department of Agriculture, Washington, D.C., 1957).

on vegetation and on wildlife. Actually, the biota of any specified continuous area, as well as the non-living features of the environment on which the living organisms depend, interact with one another to form an interrelated operating unit termed an "ecologic system," or "ecosystem" (Encyclopedia Britannica, 1975).

The living or biotic elements of an ecosystem are chiefly interrelated through the flow of energy and food. The basic source of energy that drives the ecosystem is radiation from the sun, which green plants use in converting inorganic material and other nutrients from water and the soil into the organic nutrients needed for their growth. This process, known as photosynthesis, provides the basic fuels for life systems, carbohydrates, and also the precursors for amino acids and the protein building-blocks necessary to animal life (including man). When chlorophyll molecules of green plants are activated by light, energy is released and water molecules are split; some of the results are used directly for the plant's own life processes.

The green plants as producers thus stand at the origin of what is often termed the food chain or "grazing chain." The organic matter produced by plants (the biomass) can be directly consumed by animals that have the proper feeding mechanisms (e.g., tongue, teeth, beak) and digestive systems to handle plant materials. Such animals are "herbivores;" they extract about 10 percent of the energy stored in the plant materials. Animals that eat flesh or prey on other animals are "carnivores," or "raptors," in the case of birds. Some forms of life have teeth to deal with both plant and animal materials and a digestive system that can handle at least some of both; these are "omnivores." The carnivores extract about 10 percent of the energy contained in the body of a herbivore or other carnivore. The plant-herbivore-carnivore relationship is often called a "grazing chain" or "food chain" (e.g., lettuce, rabbit, fox). Establishing other linkages (e.g., that a rat can eat lettuce, that the rabbit can eat carrots and be eaten by snakes, or that foxes also eat squirrels) creates a food web.

In addition to the biomass, organic matter on the soil surface (litter) or mixed with the soil (humus) is available for consumption, as are the products of death and excretion of plants and animals. This matter is decomposed and utilized by bacteria, other microorganisms, and some non-green plants, usually lumped together as decay organisms or organisms forming a decay chain. This cycle within an ecosystem is presented schematically in Figure IV-3.



Source: Woodell, George M., "The Energy Cycle of the Biosphere," Scientific American, 223:67, September, 1970.

FIGURE IV-3

SCHEMATIC OF ENERGY CYCLE AND FOOD CHAIN WITHIN AN ECOSYSTEM

Land Cover/Vegetation

Much of the Western United States seems uncommonly inhospitable, with sharp changes in temperature from season to season and from night to day, with unpredictable precipitation. As contrasted with areas to the east, where rainfall is more abundant, even small actions seem to cause undeservedly severe responses, which may be irreversible or take a long time-span to recover from. The arid biotic provinces are particularly prone to adverse effects; however, dry areas occur even within those that receive more annual precipitation. Thus, eastern farming practice led to the dust bowl conditions, eastern methods of irrigation led to alkaline and saline soils, and the European method of artificial pasturing and overgrazing led to weedy land and loss of grasses.

The vegetation also has a perilous existence, established over a period of decades. Seeds cannot germinate in crusted soils; they are slow to germinate in the waterlogged soils that warm slowly in the spring. An altered soil chemistry -- e.g., high levels of sodium and boron, radically different pH, or insufficient mositure -- can alter the vegetation or even eliminate it.

For the purpose of these considerations, the land cover may be broken down into seven categories (Table IV-3).* The first six of these are vegetated. The categorization is based generally on elevation and climate.

Some of the most fragile community types are the alpine and tundra regions. Due partly to thin soils and harsh weather conditions, vegetation does not readily reestablish itself once it has been disturbed. These areas should be avoided wherever possible and severe restrictions placed on construction activities in areas that must be used.

Grassland, shrubland and chaparral are all considered under the heading of rangeland. For such types of cover, minimal disturbance to the soils and careful control of erosion are necessary to avoid or minimize nutrient cycling and chemical interactions among plants as well as to prevent soil loss.

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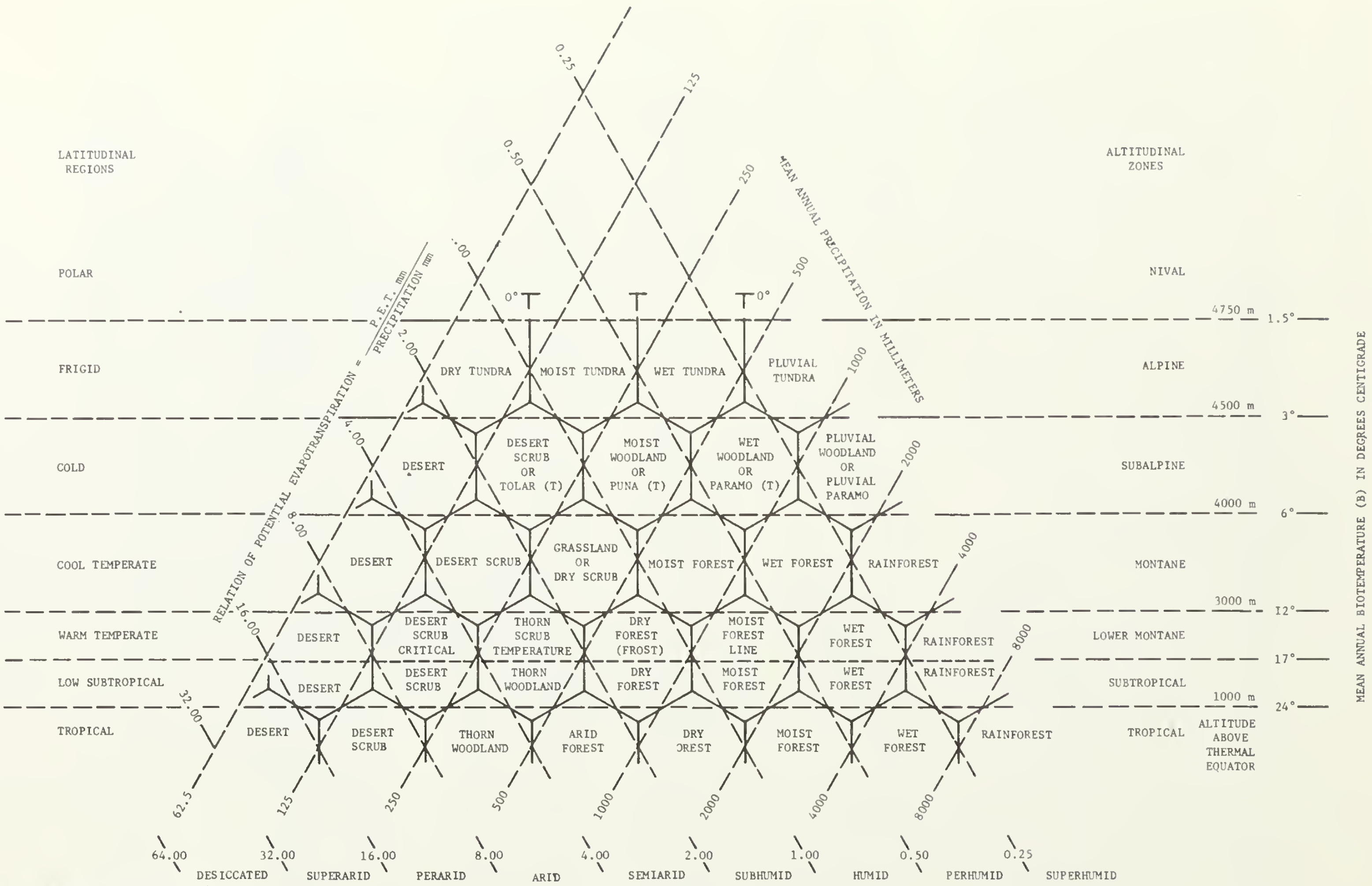
* A slightly different categorization based on interrelation of a set of governing factors is presented in Figure III-4 and discussed at the end of this subsection.

TABLE IV-3

LAND COVER AND VEGETATION SYSTEMS

- Alpine and Tundra
- Woodlands and Forests
  - Deciduous
  - Coniferous
  - Mixed
- Rangeland
  - Grass
  - Chaparral
  - Scrub
- Irrigated
- Other Cultivated
- Wetlands
- Barren
  - Salt Flats
  - Beaches
  - Desert
  - Exposed Bedrock
  - Permanent Snow and Ice Fields
  - Other

Source: Adapted from Anderson, J.R., Hardy, E.E., and Roach, J.T., "A Land-Use Classification System for Use with Remote Sensor Data", Circular 671, U.S. Geological Survey, Washington, 1972.



$B = \frac{\Sigma \text{MEAN MONTHLY TEMP} > 0° \text{ C}}{12}$

T = IN TROPICAL REGION ONLY

FIGURE IV-4

SYSTEM FOR CLASSIFICATION OF LANDCOVER AND VEGETATION ZONES

Source: Holdridge, L.R. "Determination of World Plant Formations from Simple Climatic Data", Science, 105:367-368 (1947)

Most irrigated lands are formerly arid lands reclaimed for agricultural use. However, in some areas where there is considerable rainfall, such as in the western portions of Oregon and Washington, supplemental irrigation is practiced. General considerations for irrigated lands include those for other cultivated areas, but there are additional constraints for irrigated lands. Clearly, excavation for pipelines or for power line towers must not disturb the drainage or water flow patterns. In general, flood irrigation poses no problems for power lines, but there are difficulties when a line must pass through an area where sprinkler systems are used. It is necessary to string the lines at a high enough level to ensure that the sprinklers will not affect conductors and insulators. Large center-pivot sprinkler systems severely constrain the possible routing across land so irrigated. These sprinklers move in a circle, typically of 1/4-mile radius, within which no towers or other structures are permitted. Where the land is divided into segments a quarter mile square with one such pivot sprinkler centered in each, towers to provide a 1320-foot span can be placed only in the corners so as to avoid the circle traced. In some situations, irregular spacing or overlapping of the pivot sprinklers precludes such placement so that the area cannot be crossed by a transmission line. A potential hazard exists with hand-moved sprinkler systems, representing an older irrigation practice. In moving the long pipes in order to reset them, there is a danger of affecting the conductors. Chemicals and fertilizers added to the irrigation systems increase the theoretical danger of flashover from a conductor to the ground. The pulsating spray does not pose much hazard as long as the water is relatively pure. However, the mixing of chemicals and fertilizers into the water makes it a conductor.

All cultivated lands are important from the point of view of minimizing the loss of productivity caused by the construction and maintenance of the utility. Revegetation and possible ecologic pact usually create less of a problem, however, than do the possible consequences for agricultural use.

Wetlands are extremely productive communities that provide breeding and spawning grounds for many important species of birds and other wildlife as well as performing many other necessary functions for local environments. They are also quite fragile and should be preserved as close as possible to their natural state. Access roads could easily disrupt the water and nutrient circulation and subsequently ruin large parts of the habitat. Disturbance of these areas should be avoided if possible. Sometimes, it may be possible for transmission lines to span small wetland areas completely so as to preclude the possibility of any significant impact.

The category of barren lands includes some that may have no vegetative cover as well as those in which patches of tufted grass, brush, or other sparse growth alternate with the exposed surface of the earth. In completely bare areas, no direct impact on vegetation is possible by definition. However, there may be fauna present, such as burrowing creatures, insects, and other invertebrates that nest below the surface. Beach areas without vegetation are sometimes frequented by worms, some of which may have significant commercial value in a specific situation, such as bloodworms harvested for fishing. Sparse vegetation supported by barren lands is likely to be part of a particularly fragile ecosystem, easily damaged by disruption of the earth surface. The potential impact in terms of numbers of species and total population that can be affected may be relatively slight compared to areas with greater diversity and higher density. At the same time, the resilience of the biota is less and the species affected often include those whose numbers are dwindling so that the probability of an irreversible adverse impact tends to be high.

Type of land cover can be measured in terms of the percentage of a given area covered by each type and/or number of linear miles affected. These results can be tabulated for a proposed route or utility line location to give a quantitative profile of the vegetation and land cover that will be affected. Alternative line routings can be compared on this basis. Such a measure does not take into account the different potentials for adverse impacts on the various types of land cover; this consideration, in large measure, governs suitability for locating a utility line. One important consideration is the abundance of a given type of cover in the general region where the line will be placed. For instance, the riparian woodlands of the Southwest are considered especially sensitive and should be avoided, whereas the riparian woodlands of areas with bountiful water are hardy communities that can quickly recover from most disturbances. The primary reason is that since water is scarce in the Southwest, the extent of these communities is quite limited. Therefore, the destruction of a part of an already small community or ecosystem will displace a significant percentage of the fauna inhabiting it. This situation creates a load on the remaining area, raising the danger that it may not be able to accommodate all of the displaced wildlife and that they may not be able to find a suitable habitat elsewhere in the region.

One measure of the importance of a type of land cover is the percentage of total area it represents in a broad region, such as the biotic province in which it is located, the entire study area of the proposed utility line, or the total area of all the states through which the line will pass. Weights representing the importance of avoiding a particular type of land cover (which is the inverse of a measure of suitability for line location) could then be assigned, proportional to the percentage factor for that type.

Further considerations affecting suitability of land cover are presented below in the subsection on Stability/Sensitivity.

Stability/Sensitivity of Ecosystems

An important consideration affecting the impact on an ecological system as a whole, as distinguished from the effects on individual plant and animal species, concerns the stability of the system. Stability in this context is the opposite of sensitivity and denotes the ability of an ecosystem to withstand impacts and its resilience in adjusting to transient perturbations, such as may be introduced by construction of a utility line. In highly sensitive ecosystems, disruption of a few factors or even a single element in the energy or food cycle can lead to irreversible deterioration. Extreme examples are excavations where a fragile topsoil is removed, erosion follows, and the capability to sustain life diminishes to the vanishing point; or where the hydrology of wetlands is disrupted, significant portions dry up, and, along with the aquatic flora, breeding grounds for waterfowl and other wildlife are destroyed. Utility lines do not consume large expanses of acreage so that their potential for adverse impact may be deemed less severe than major construction projects, such as power plants or airports, or even than bad farming practices. Nevertheless, it is certain that utility lines in sensitive ecosystems will tend to have a much higher potential for adverse effects from long-term chain reactions than will lines in stable systems.

Stability of an ecosystem depends on many factors affecting growth rate of forms of life and the complexity of the food chain or web. Principal factors include soil quality, climate (which affects growth rate and length of growing season, particularly through temperature and precipitation), the diversity of species (which affects the richness of the food web and the presence of alternate paths by which the cycle can be completed if one link is lost), and the variability of the system in providing a range of habitats for its life forms.

Thus, of two locations under consideration for a utility line, the more suitable one in terms of ecosystem stability will be (other things approximately equal) the one characterized by:

- Good soil, deep and fertile, favoring regrowth of vegetation
- Warm or mild climate, providing an adequate growing season
- Abundant rainfall, promoting fertility
- High diversity of species
- Abundance of habitats, especially for the most important species of flora and fauna

Sensitivity can be determined in relation to the type of land-cover that is basic to the ecosystem. One scale and classification system suitable for the purpose, shown in Figure IV-4 (Holdridge, 1947), is somewhat similar to the categorization of Table IV-3. It is based on a rather complicated system of interrelated parameters, chiefly temperature and precipitation, but includes also latitude, altitude, and what is termed "relative potential evapotranspiration."

The triangular or pyramidal structure in Figure IV-4 contains types of land cover that may occur under specified conditions of temperature, humidity, latitude, and altitude, as indicated by the scales along the margin. The vertical scales along the left and right margin represent the fact that some approximately equivalent climatic and temperature conditions may be produced by variations in either latitude or altitude. Thus, the conditions that produce tundra may exist in frigid latitudinal regions regardless of elevation or at great mountain heights (the alpine altitudinal zones) within what are regarded geographically as the temperate zones of the earth. Both latitudinal regions and altitudinal zones are defined quantitatively in terms of mean annual biotemperature in degrees centigrade. The mean annual biotemperature is defined as the average of the monthly mean temperatures above freezing (0°C), where any monthly mean temperature below freezing is scored as 0.

The bottom horizontal axis gives, in qualitative terms, levels of humidity ranging (left to right) from desiccated to superhumid. These levels are reinforced by diagonal lines representing the relative or potential evapotranspiration rate. The numerator denotes (in millimeters) the sum of the rates of evaporation and transpiration (i.e., the rate at which water is lost by the vegetative tissues as distinct from evaporation from surfaces). The right diagonal scale gives mean annual precipitation in millimeters.

The intersection of all these four scales defines a point of land cover comprised within some designated type. The hexagonal shape of the boxes bearing the name of a particular kind of land cover emphasizes symbolically the fact that boundaries between types of vegetative cover do not coincide neatly with divisions formed by values of these parameters.

To use the classification and the scales as general guidance in impact assessment, it is not necessary to have exact values for any of the parameters. The point is that as one moves upward in the vertical scale and to the left on the horizontal one, one encounters types of land cover associated with greater sensitivity of ecosystems and less resilience in recovery from impact. Unless closely maintained, a corridor cleared through a rain forest will restore itself with little or no trace of any secondary effects. On the other hand, desert land or scrub at any latitude and tundra in frigid zones or high mountain regions tend to be fragile, with the relatively fewer life forms more easily damaged both by primary and secondary impacts.

Two types of land cover listed in Table IV-3 which are not provided for by the Holdridge system in Figure IV-4 are irrigated land and wetlands. Both tend to be highly sensitive to the impact of utility lines and the importance of avoiding them should be reiterated.

Species Diversity

Species diversity is determined by the number and type of species -- both of vegetation and of wildlife -- in a given area. The simplest method of measuring diversity is just a count of the number of different species present, as attested by previous documentation and by observation undertaken in monitoring the environmental characteristics of potential routes. An accurate determination of the species of flora and fauna that will be encountered is important in order to estimate the potential impact, since the effects of construction, operation, and maintenance of the line are obviously not the same for all forms of biota. Such baseline studies sometimes disclose the presence of previously unsuspected species in a particular locality. In particular, it must be determined whether or not any rare or endangered species (as discussed further below) is present.

Diversity of species is also a measure of a community's or ecosystem's richness in life forms. In assessing alternative locations for a line or segment, the considerations affecting impact on individual species may be somewhat at variance with those affecting the ecology as an integrated system. It is obviously desirable to harm as few species as possible and to exclude utility lines particularly from those areas where the impact would be significantly adverse on a number of different types of vegetation and wildlife. On the other hand, species diversity is at least a partial indicator of ecosystem stability--i.e., how much resilience the system has in maintaining itself and adjusting to temporary perturbations such as may result from a line. Thus, in considering the long-term and less predictable effect of a utility line on the ecosystem, where only minor impacts are expected on any individual species, the area with greater diversity may, other things being equal, offer an advantage for locating a corridor. Stability is considered further in another subsection.

Characteristics of Individual Species

Most areas through which a utility line might pass have so many different types of plants and animal life that it would not be feasible to characterize each one or to consider all the varieties in assessing the impact. Which species or classes are considered individually can largely be determined on the basis of how important the particular plant or animal type is and how vulnerable it appears to be to potential adverse impacts.

Importance

Clearly, the dominant species on a quantitative basis are especially important in the ecology of a given area and occupy a significant role in terms of what the environmental impact will be. It is not likely that precise statistics as to the diversity of particular plants or animals along a proposed utility route will be required. Estimates sufficiently accurate to reflect the relative ranking of the major types should serve to characterize the biota of a specific area within a proposed line location and to establish how far the flora and fauna of the specific locality deviate from those of a larger region such as the biotic province or specific life belt of which it is a part. Sampling estimates of plant types are of course easier to obtain than of animal populations. Dominant forms of plant life are typically given in terms of percentage of an area covered by a particular type of tree, grass, or other form of plant life. Relative frequencies of animal populations can be estimated not only from visual observation conducted for the purpose, but also from live trapping (sometimes conducted as part of an environmental baseline study), from roadside kills (for portions of an area traversed by a highway), and from counts of game animals bagged during hunting season. Further discussions of methods can be found in literature on wildlife management (Dasmann, 1966; Whittaker, 1970).

Particular plants and animals may take on significance over and above their numerical strength in terms of the role they occupy in the ecosystem. For example, specific grasses, shrubs, or trees may have special importance for birds or animals as forage crops, in providing nesting and/or breeding areas, or as cover for game. Specific forms of animal life can fill a role in the food chain and in keeping the system in balance. Hawks, owls and other raptors sometimes provide an important check on the proliferation of rodents, as do foxes and other small carnivores. Grazing animals, by their preference for particular grasses or shrubs, may have a part in maintaining a prevailing balance among types of ground cover. Because of the great variety and combination of conditions that can be found, it is impossible in these considerations to specify the various ways particular plants and animals can function in the ecologic balance or which species are most likely to do so. In assessing environmental impact, it is important to determine whether any particular species that play a critical role have been identified in baseline studies or in biological investigations of a region and to establish how those species would be affected by a utility line.

Vulnerability

Vulnerability of individual species is important in assessing potential environmental impact. Plants which can grow only under restricted conditions are obviously more susceptible to adverse effect when the environment is changed than are those with broader tolerance. Wildlife particularly can experience adverse secondary effects. Each species has a preferred habitat, which can be quite varied or extremely restricted. The habitat can be described as a range of tolerable conditions of temperature, altitude, and the availability of water and food. The size of the physical area populated by each species is an important parameter when determining the effects of removing or changing a certain fraction of it for use as a corridor.

The distribution of species within a given region in relation both to the area required for life support and to the overall frequency of the species is important in terms of its vulnerability and its inherent importance. In this sense, large forms of life, both plant and animal, are more vulnerable. A tree requires much more soil area to provide nutrients than a shrub or tuft of grass and, in considering the potential impact of disturbing adjacent land, the effect on stands of trees will tend to be more significant than the effect on small plants. Whereas a squirrel or burrowing rodent may be able to find sustenance within a limited radius of its nest, a large animal may have to graze over broad areas or roam extensively to find its prey. The emphasis in environmental assessments should take such differences into account. Information on more precise ways of determining carrying capacity or biomass may be found, if necessary, in handbooks on conservation and wildlife (Dasmann, 1966; Philipps, 1959).

Endangered Species. Certain species are considered to be rare, endangered, or threatened for various reasons, including low adaptability, a severely restricted habitat, or lack of tolerance of human activity. The presence of such species may indicate other problems in the local ecosystem. The habitat of such species should be avoided if at all possible.

Threatened and endangered species of wildlife are legally protected by the Endangered Species Act of 1973 (Public Law 93-205; 87

Stat. 884). This act defines endangered species as those species in danger of extinction throughout all or a significant portion of their range and threatened species as those species likely to become endangered within the foreseeable future throughout all or a significant portion of their range. A list of the endangered fauna inhabiting the Western U.S. is given in Table IV-4. Since the list is continuously being revised, an updated version should be consulted. The Office of Endangered Species and International Activites, U.S. Department of the Interior, Washington, D.C., publishes a list and description of the Threatened Wildlife of the United States and the Smithsonian Institute has just completed a report on the Endangered and Threatened Plant Species of the U.S. (1975).

Environmental Impacts

It can be readily appreciated that because of the interrelationships within ecologic systems, the potential for environmental impacts on living organisms can often be quite complex. Direct effects on one part of the ecosystem, such as removal of vegetation or change in soil nutrients, may be manifested in terms of the indirect impact on another element, such as on wildlife dependent upon particular plants for grazing.

Utility corridors are sources of potential impacts on the native ecosystems because of these factors:

a. Permanence
b. Possible creation of a linear path between dissimilar ecosystems
c. Need to keep the corridor relatively clear
d. Periodic maintenance--continuing activity along right-of-way and access roads, including mechanical cutting, use of herbicides, etc.
e. Access to previously undisturbed areas in some cases
f. The physical presence of structures in the corridor

The most noticeable and well known effects are due to clearing and other construction activities. Clearing activities are generally more extensive for pipeline construction than for power lines, due to the need for continuous trenching along the route. However, with power lines, the need for access roads in particular ensures that clearing remains an important consideration. Although potentially adverse impacts are those that cause greatest concern, clearing for a utility ROW can also have beneficial environmental effects when properly carried out.

Erosion by wind and water are omnipresent threats when the vegetation has been qualitatively altered or quantitatively reduced.

TABLE IV-4

ENDANGERED FAUNA OF THE WESTERN U.S.

COMMON NAME	SCIENTIFIC NAME	WHERE FOUND
BONY FISHES (Class Osteichthyes/Phylum Chordata)		
Trout, Salmon, & Relatives (Order: Salmoniformes)		
Trout, Arizona (Apache)	Salmo sp.	Arizona
Trout, Gila	Salmo gilae	New Mexico
Trout, Greenback cutthroat	Salmo clarki stomias	Colorado
Trout, Lahontan cutthroat	Salmo clarki henshawi	California Nevada
Trout, Paiute cutthroat	Salmo clarki seleniris	California
Carps, Minnows & Relatives (Order: Cypriniformes)		
Bonytail, Pahranagat	Gila robusta jordani	Nevada
Chub, Humpback	Gila cypha	Arizona, Utah, Wyoming
Chub, Mohave	Siphateles mohavensis	California
Cui-ui	Chasmistes cujus	Nevada
Dace, Kendall Warm Springs	Rhinichthys osculus thermalis	Wyoming
Dace, Moapa	Moapa coriacea	Nevada
Squawfish, Colorado River	Ptychocheilus lucius	Colorado R. system
Woundfin	Plagopherus argentissimus	Utah
Silversides, Topminnows, and Relatives (Order: Atheriniformes)		
Killifish, Pahrump	Empetrichythys latos	Nevada
Pupfish, Devil's Hole	Cyprinodon diabolis	Nevada
Pupfish, Owens River	Cyprinodon radiosus	California
Pupfish, Tecopa	Cyprinodon nevadensis calidae	California
Pupfish, Warm Springs	Cyprinodon nevadensis pectoralis	Nevada
Topminnow, Gila	Poeciliopsis occidentalis	Arizona
Sticklebacks, Pipefishes, and Relatives (Order: Gasterosteiformes)		
Stickleback, Unarmored threespine	Gasterosterus aculeatus williamsoni	California

TABLE IV-4 (Continued)

ENDANGERED FAUNA OF THE WESTERN U.S.

COMMON NAME	SCIENTIFIC NAME	WHERE FOUND
AMPHIBIANS (Class Amphibia/Phylum Chordata)		
Salamanders (Order: Urodela)		
Salamander, Desert slender	*Batrachoseps aridus*	Riverside C'ty. California
Salamander, Santa Cruz long-toed	*Ambystoma macrodactylum croceum*	California Santa Cruz C'ty.
REPTILES (Class Reptilia/Phlyum Chordata)		
Lizards and Snakes (Order: Squamata)		
Lizard, Blunt-nosed leopard	*Crotaphytus silus*	California
Snake, San Francisco garter	*Thamnophis sirtalis tetrataenia*	California
BIRDS (Class Aves/Phylum Chordata)		
Ducks, Geese, Swans and Relatives (Order: Anseriformes)		
Duck, Mexican	*Anas diazi*	New Mexico, Texas, Arizona
Goose, Aleutian Canada	*Branta canadensis leucopareia*	Western U.S.
Eagles, Falcons, Vultures, and Relatives (Order: Falconiformes)		
Condor, California	*Gymnogyps californianus*	California
Eagle, Southern bald	*Haliaeetus leucocephalus leucocephalus*	So. of 40th Parallel
Falcon, American peregrine	*Falco peregrinus anatum*	Pacific Coast East to Rocky Mtns., Arizona
Pheasants, Grouse, Curassows and Relatives (Order: Galliformes)		
Quail, Masked bobwhite	*Colinus virginianus ridgwayi*	Arizona New Mexico
Cranes, Rails, Bustards and Relatives (Order: Gruiformes)		
Rail, California clapper	*Rallus longirostris obsoletus*	California
Rail, Light-footed clapper	*Rallus longirostris levipes*	California
Rail, Yuma clapper	*Rallus longirostris yumanensis*	California Arizona

TABLE IV-4 (Concluded)

ENDANGERED FAUNA OF THE WESTERN U.S.

COMMON NAME	SCIENTIFIC NAME	WHERE FOUND
Plovers, Snipes, Gulls and Relatives (Order: Charadriiformes)		
Tern, California least	Sterna albifrons browni	California, South San Francisco Bay to Baja Calif.
Perching Birds--Sparrows, Larks, Thrushes and Relatives (Order: Passeriformes)		
Sparrow, Santa Barbara	Melospiza melodia graminea	California
MAMMALS (Class Mammalia/Phylum Chordata)		
Rodents (Order: Rodentia)		
Kangaroo Rat, Morro Bay	Dipodomys heermanni morroensis	California
Mouse, Salt marsh harvest	Reithrodontomys raviventris	California
Prairie Dog, Utah	Cynomys parvidens	Utah
Carnivores (Order: Carnivora)		
Ferret, Black-footed	Mustela nigripes	Dakotas, Montana South to New Mexico, and Texas
Fox, San Joaquin kit	Vulpes macrotis mutica	California
Wolf, Northern Rocky Mountain	Canis lupus irremotus	Wyoming, montana
Even-Toed Ungulates (Order: Artiodactyla)		
Deer, Columbian white-tailed	Odocoileus virginianus leucurus	Oregon Washington
Pronghorn, Sonoran	Antilocapra americana sonoriensis	Arizonia

Source: Threatened Wildlife of the United States, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C., March, 1973.

Raindrop impact on the soil, sheet erosion, and gullying are well-known phenomena. The nutrients and sediments released by utility line construction activity can have an immediate deleterious effect on inhabitants of the stream carrying them. The animal populations that rely on the vegetation for life support are similarly affected. Fatalities and emigration are possible results.

Clearing of an extensive corridor can also open up the area to competing species and blight. The spread of fungi, insects, and exotic species of plants or animals along the resulting corridor could, in some instances, be significant. Bark beetles and grasshoppers are among the pests that can spread more rapidly through the clearing. Removal of major amounts of the native vegetation from the right-of-way can make the cleared area an ecotone, or boundary, of an existing community in which there is high biologic activity.

Some types of wildlife travel in long yearly migrations, passing through many variations of habitat. These animals can usually tolerate a wide range of conditions. The main concern for corridor development in these cases is not to disrupt the migrations. Therefore, construction activity should be timed so that it will not coincide with migratory periods. This concern also precludes large-diameter unburied pipelines and other linear obstructions, such as fences, in these areas. Other important features of the habitat should be identified. These include breeding grounds, nesting areas, watering spots, and major food sources. Special care should be taken to avoid them.

Many potential environmental impacts of construction are associated with particular types of vegetation and land cover (as considered in the subsection above). The type of land cover most susceptible to adverse effects is the one least attractive for routing a utility line. However, the emphasis in considering potential impacts should be to insist on suitable construction techniques known to experienced utility companies, which can minimize or prevent environmental degradation when a line is routed through a particular type of land.

In woodland areas, the number and type of trees that will be eliminated are of concern. Important considerations include the frequency of distribution, life span, and time to maturity of the types of trees affected. It is potentially more serious to eliminate stands of long-lived trees requiring many years to reach full growth than vegetation that will replace itself more readily. Survival of vegetation that is very numerous in an area will be less severely affected by clearing operations that reduce its number than will a rare species. In this connection, a significant consideration is the relationship of construction clearance to other operations practiced on multiple-use rights-of-way, such as commercial or government timber harvesting. In many instances, the clearing required for a ROW may fit the existing pattern of operations conducted in woodland.

Other factors that are concerned primarily with wooded areas are the height and extent of their canopies. Food supply for browsing animals is scarce in a high canopied climax forest. The tall trees inhibit the penetration of light to the forest floor, thereby preventing the growth of low plants and shrubs that feed small animals. The removal of parts of the canopy for corridor rights-of-way allows lower vegetation to grow along the edges of the cut. This effect helps to prevent erosion and provides food for wildlife. Clearing can also provide migratory paths for some forms of wildlife and feeding or nesting areas for those birds and small mammals that prefer the "edge zones" between cleared and cultivated or wooded areas. Wild turkeys, for example, thrive on the insects along the edges of a cleared right-of-way. Thus, the biological impacts of a utility line are likely to include beneficial effects if exact location of the ROW and construction and maintenance practices are closely coordinated with game management and wildlife conservation officials.

In rangeland, any extensive soil damage begins the cycle of vegetation loss, followed by wildlife loss. With this type of land cover, wind can provide a strong force for erosion. Rangelands are frequently quite dry and, therefore, recover slowly once they have been disturbed. Overgrazing and the resultant formation of dust bowls is a prominant example of the results of mismanaging rangelands. Revegetation following construction requires a knowledge of the original vegetation.

An accidental adverse impact which can result from improper post-construction activities, particularly in grazing areas, is termed "hardware disease" by the Bonneville Power Administration (Hellman, 1974). Breakaway bolts and other small metal objects often remain on the ground after construction. Unless a thorough cleanup of the construction area is carried out, these metal items are likely to be ingested by ruminants and other grazing animals, often with fatal consequences when the metal pierces the digestive organs.

In many sandy, arid regions, the fine particles are selectively removed from the soil surface by wind action. This results in the formation of a desert pavement, a soil surface composed exclusively of large-grained sands and pebbles which are too heavy to be easily removed by average winds. Any disturbance of this pavement, such as road building or trenching or even driving over the open range, can cause severe erosion to occur in the disturbed areas. This phenomenon is of importance in the most arid and sparselv vegetated regions as well as in the completely barren deserts.

Manipulation of the soil (e.g., grading and moving of heavy equipment on treads or wheels) results in disturbing and/or rearranging the surface layers of soils. This impact is of particular consequence to cultivated lands. The factors involved are type of soil, moisture content when manipulated, slope and season. The formation of new soils by mixing, exposure of new surfaces by removal of the cover, churning, compaction and drying are the end products. Post-construction impacts include barriers created to proper restoration of a stable and fertile land surface. For example:

a. Compaction irreversably alters the soil permeability to air and water.

b. Ruts alter surface moisture accumulation; standing water could lead to saline or alkali soils or waterlogging or could provide breeding places for mosquitoes; dry holes can impede the movements of wildlife, livestock and farming equipment.

c. Changes in soil fertility and new combinations of soil materials, available moisture and organic matter are critically important in establishing productive use of the land.

There are likely to be serious erosion problems in barren lands, such as occur from disruption of desert pavement and increased vulnerability of exposed buttes, cliffs, ravines, etc., in so-called badlands. On flat barren lands, the most severe effects can be expected from wind and rain stirring up the soil, which leads to sedimentation, interference with cycling of nutrients and other elements, and smothering of vegetation where redepositing occurs. On slopes, these effects are most severe from downhill disturbances of slides and heavy runoff. The impact may be aggravated on snow and ice-covered barren slopes as a result of avalanches. Salt flats may pose a problem of corrosion, especially during moist periods. Sandy beaches may require, in addition to protection on grounds of esthetics and compatible land use, assurance that construction activities will not result in deterioration of soil stability leading to increased erosion from tidal action.

Normal operation of utility lines tends to have very little impact on terrestrial ecology, although any accidents which occur during operation of a line can have serious consequences. Pipeline ruptures could release into the environment petroleum products or other contents which are directly noxious to biota and can also contaminate water sources on which terrestrial as well as aquatic life depend. Fires resulting from lightning strikes or other accidents to power transmission lines not fully protected by adequate safety measures could devastate the biota, particularly of relatively arid regions covered by stands of dry vegetation. This potential threat underlines the importance of standard safety precautions.

In this connection,it should be remembered that in wilderness areas fires occur naturally. In climax forests,they sometimes perform a function in ecologic balance and development by burning down some of the forest and thus allow proliferation of lower vegetation which supports a more varied wildlife. The somewhat remote possibility of forest fires resulting from power lines in wilderness areas needs to be considered in the light of the uncertain effect of confining and extinguishing "natural" fires in such regions.

A potential impact that could easily be overlooked is the threat to hawks, eagles, and other raptors from electric lines that support the pipelines. As noted in Section V, pipelines require power for such purposes as operation of compressor and booster stations at widely spaced intervals. The power is supplied at distribution voltages at or below the 69 kV level, which distinguishes transmission lines from distribution lines. Loss of raptors by electrocution has been observed on distribution lines (Boeker and Nickerson, 1973). The large birds land on wood areas or pole tops in such a way that, because of their considerable wing spread, they make simultaneous contact with more than one conductor, or with the ground wire and energized parts on a pole carrying a transformer. On transmission lines, the spacing is so great that even the largest raptor is highly unlikely to make such simultaneous contact. But on many distribution lines, the conductors and ground wires have a relatively narrow spacing and they are not insulated, so electrocution occurs. In addition to the large raptors (hawks, eagles, and owls), which traditionally perch on elevated sites, electrocution of egrets, herons, crows, and even wild turkeys has been documented. Losses have been greatest in the mountainous Western states (Boeker and Nickerson, 1973). Such electrocutions can be prevented by application of simple measures in engineering lines for distribution of electric power, as discussed in the subsection on Mitigating Measures (U.S. Department of Agriculture, Rural Electrification Administration, undated).

The foregoing discussion is not meant to imply that power delivered to pipeline poses a particularly large danger to raptors. Indeed, the power delivered to a pipeline is likely to be much less than that required for other development in the same area. It is merely intended to point out that adequate precauations should be taken in regard to power lines supporting a pipeline, as with any distribution line below 69 kV.

If there are any other impacts on terrestrial ecology due only to the presence and normal operation of an energy corridor once the line has been constructed, they are poorly understood and generally undocumented. It is possible that a slight change in ground temperature could be caused by the fluids flowing through a pipeline. It is known that transmission lines may induce voltage in metallic objects or in the soil beneath if not properly grounded (Section V). Studies to determine the environmental effects of electric fields are currently in progress.

Mitigating Measures

Prevention or mitigation of potential adverse effects on the terrestrial biology begins with sound construction practices which minimize erosion and other disturbance to the soil. Soil damage begins the cycle of vegetation loss, followed by derangement of the cycles on which the ecosystem depends and by wildlife loss. Compaction leads to lowered permeability and lowered moisture content. Puddles of water result in crusting of the soil so that seeds cannot germinate. A rise in the watertable (to within 5 feet of the surface) can lead to the formation of saline or alkali soils. Disruption of the surface, rearrangement of the surface layers, or exposure of new layers presents a new array of soil chemistry reactions. Maintenance of adequate drainage during and after construction is important. Topsoil must be replaced, if necessary brought in, to restore what has been lost in construction of the line and access roads. Care is required to ensure that drainage patterns are not inadvertently altered; changes can lead indirectly to change of vegetation as well as to drying up of water sources on which wildlife depend.

In revegetation following construction, hydraulic planting has been found effective, especially on slopes too steep for conventional machinery (Electrical World, August 15, 1972). Such revegetation requires a knowledge of the flora prior to construction. In areas already documented, a field check to confirm the current conditions should be made. In areas not previously studied, transects along the ROW should be made to indicate the principal species of vegetation and relative abundance. Care should be taken to avoid introducing exotic or weedy species to an area.

Selective cutting for the ROW is important to minimize removal of vegetation and maintain cover for birds and other wildlife. In particular, during initial surveying clearing for sight lines should be held to the minimum necessary for obtaining readings. Survey lines as well as the final centerline for the ROW should take into account tree size so as to avoid cutting the largest trees. It is important to treat wounds resulting from accidental damage (as by impact from heavy equipment) or from topping or otherwise cutting parts of trees not felled so as to minimize vulnerability of the tree from insects and decay. In removing felled timber for utilization, the Bonneville Power Administration follows a practice known as "yarding," in which the tree butt is held clear of the ground so that there is a minimum of disturbance to the surface. For this operation, a spar tree or hydraulic extendable portable tower of tubular steel is used through which steel cable lines for hoisting are run. The operation is particularly applicable where trees are felled on sloping terrain, then yarded uphill by the hoisting tower placed at the crest. Yarding by helicopter in particularly sensitive areas is also performed by BPA (Hellman, 1974).

Mating, feeding, and nesting grounds should be avoided in favor of other areas where the regional fauna will be less sensitive. Pipelines placed above ground should not be allowed to cross migratory paths of deer or other wildlife where they can act as a barrier. Transmission towers, however, appear to pose no barrier to deer or other large forms of wildlife. Bird sanctuaries represent particularly sensitive areas; power lines especially can pose a hazard at points in the flight path where flocks of birds would be rising from the ground or coming in to land at a shelter area. For migratory birds in flight, the question of whether transmission lines pose an actual hazard requires more research.

Scheduled maintenance should be arranged to avoid the breeding season as much as possible. During this point of the reproduction cycle, birds and small burrowing mamals are particularly vulnerable, nests may be destroyed, and the young can be exposed before they become self-sustaining. In the use of herbicides for vegetation control along the ROW, spray drift can result in damage to non-target flora as well as fauna. Careful monitoring of herbicide application is required to minimize secondary effects. In particular, vegetation is sensitive during the maximum rate of growth period and should be protected from inadvertent contact with herbicides resulting from downwind drift or careless application.

AQUATIC BIOTA

The primary concern of this section is the effect of utility line construction, operation,and maintenance on aquatic ecosystems.

Construction

Utility line construction activities either adjacent to or within surface waters can affect aquatic ecosystems. On-land construction of a ROW adjacent to a surface water system may affect aquatic life through the introduction of various materials into the water body by overland runoff. The primary constituents of such runoff are clay and silt particles and other surface materials which are eroded by the runoff as it crosses areas cleared in the construction of the ROW, access roads, or staging areas. Material transported from these areas frequently contains inorganic and organic matter originating from decayed vegetation and from the soil itself. In addition, overland runoff may leach minerals from the exposed soils or may carry residues of pesticides or herbicides used during the construction period or resident in the soil. Another pollutant which may be contributed from construction activity is waste oils and grease from construction machinery. The exact quantities of these various pollutants which enter a given water body depend, to some extent, on the natural conditions at the site and, to a larger extent, on the care taken by the contractor to minimize their flow.

Utility line construction can also affect aquatic biota by direct construction activities in a surface water body. Some of the potential effects are caused by substances similar to those introduced into surface waters by on-land construction. Minerals, organic material, heavy metals, nutrients, and any other material contained in disturbed bottom sediments may become suspended or dissolved in the water. Construction equipment may also introduce oil and grease. In addition, in-stream construction may affect aquatic life in three other ways: by physically altering the channel cross section, by diversion or alteration of stream flow, or by the shock wave caused by in stream blasting.

Sediment introduced into surface waters by runoff can affect aquatic life in many ways; it can clog fish gills, bury eggs of both fish and insects, bury food sources, and smother aquatic vegetation. In addition to direct effects there are many indirect ways in which sediment disrupts the aquatic system. For example, turbidity decreases light penetration, therefore decreasing photosynthetic activity of aquatic plants and phytoplankton. This effect in turn may result in a reduction of the dissolved oxygen concentration. Subsequent to the initial increase in turbidity, nutrients contained in the sediments may contribute to algal blooms which further decrease dissolved oxygen levels. These conditions can eventually lead to anaerobic bottom conditions, especially in deep water systems, which favor the production of hydrogen sulfide (H_2S), an extremely odorous gas, which dissolves in water and tends to decrease pH. This increasingly acidic condition may place further stress on aquatic life. Another significant effect of increased turbidity is the increase of water surface temperature due to the increased heat absorption of the sediment particles. The increased temperature is usually confined to water near the surface since the turbidity inhibits light and heat penetration to lower depths.

Pesticides and herbicides contained in the runoff or previously buried in bottom sediments can also have significant effects on stream biota. Oils have a coating effect similar to sediments. They also reduce light penetration and, depending on the amount of oil released, can reflect large percentages of the incident light at the water surface. Heavy metals introduced through weathering of construction equipment and metal scrap or through leaching of natural soils are known to have significant effects on all biological systems.

Channel modifications can alter water flow in downstream sections of streams and water courses. Since aquatic life is adjusted to equilibrium stream conditions, this change may be detrimental to the attached organisms growing on the bottom or stream banks. As a result of the new flow velocities, there may be a decrease of the available food supply and the diversity of the aquatic ecosystem until a new equilibrium is established.

Operation and Maintenance

The effects of utility line operation and maintenance upon aquatic ecosystems are generally minimal in all but extreme cases. These are abnormal conditions usually caused by catastrophic events. They include oil spills from ruptured pipes and extreme electric currents from grounded or broken power lines. In these cases,the event itself may have severely detrimental effects which might be accompanied by additional aquatic biota disruption due to the repair activities. The initial effects would include electrocution or suffocation of the aquatic life and, in the case of large oil spills, much of the local food supply might be covered by oils and destroyed. The effects of the repair activities might be similar to but less extensive than those of the initial construction activities.

Further impacts on the aquatic ecosystem may result due to the increased accessability of wilderness areas which may be traversed by a utility line. Human intervention would be facilitated and may stress fisheries and introduce pollutants to relatively pristine water bodies.

Assessing the Impacts

Two types of data are needed to assess the impacts of proposed utility lines on aquatic biota. The first is information on the current state of the quality of any body of water that will be affected. Useful parameters are mean and extreme flow rates and the yearly variations in concentrations of suspended solids, dissolved solids and dissolved oxygen. These and other parameters have been discussed under water quality in Section II.

The second type of data needed is information on the biota inhabiting the stream. Many of the same considerations discussed in conjunction with terrestrial wildlife also apply to aquatic life. These include identification of the types of species present, the species diversity, the ways in which different species interact with each other and their environment, and their sensitivity or stability.

In addition, many desirable species of fish are especially vulnerable during their spawning periods. For example, rainbow and cutthroat trout spawn in the spring while brown, brook, and Dolly Varden trout spawn in autumn. If there is a possibility that a particular stream functions as a spawning ground, the stream should be avoided or construction activities should be timed so as not to seriously disturb the fish during and immediately after spawning.

After the initial conditions and inhabitants are identified, it is important to determine the overall sensitivity of the aquatic ecosystem. One indicator of a fragile system is limited species diversity. Aquatic biologists should be consulted to rank the streams and lakes in the study area as to their ability to withstand the stresses caused by utility lines. The important considerations are whether damage to aquatic biota is significant and whether it will be permanent. Often a stream is able to recover satisfactorily from a temporary change in water quality and a small reduction in the numbers of a particular aquatic species need not become permanent if original water quality can be restored.

Mitigation of Impacts

If due to other siting conditions it becomes necessary to cross a sensitive aquatic area, there are measures that should be taken to minimize the resultant damage, although no mitigation methods are 100% effective. Selective cutting of vegetation, use of sediment basins and other control structures, and surface stabilization materials, such as straw or stone mulch, have been effective in decreasing the likehood that material transported by runoff will enter surface waters. Good planning to minimize cuts and fills and to "buffer" exposed surfaces with dense vegetation is also effective.

Damage from in-stream construction is more difficult to mitigate. It can be decreased by eliminating unnecessary movement of equipment in the stream and by applying stream bank stabilization techniques. As much as possible, waste oils, slash, garbage and construction debris should be prevented from entering the water. These should be removed immediately following completion of construction or maintenance. activities.

Proper timing will eliminate a major portion of the impact to fish during spawning season, providing that the stream is returned to its original condition. In some instances, restocking of fish or other aquatic biota may be necessary to ensure restoration of a satisfactory level for combined maintenance of the species affected.

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SECTION V
LAND USE AND ESTHETICS

SECTION V

LAND USE AND ESTHETICS

OVERVIEW

This section discusses the land use and esthetics that serve as determinants in the location of a utility line. Consideration of these factors is important both in choosing a location for a pipeline or power transmission line and in assessing its impact. This section addresses how and to what extent social, economic and cultural considerations determine the degree to which two sets of the objectives discussed in Section I are met: namely, those relating to effective land use and esthetic compatibility. Although many of the factors themselves are difficult to quantify, suggestions are made as to how they can be measured and how the extent of their potential impact can be assessed. Such considerations are particularly important in weighing alternative routings for a given utility line. In this process, the number of miles of land devoted to particular uses and the size of the population that will be affected by alternative segments of a proposed line can be important indicators of the relative effects that different routings may have on the human environment.

Socioeconomic and cultural factors can represent important constraints on the choice of a line routing. For example, urbanized areas and regions of high residential density, where the number of people affected tends to be large, are usually avoided by utilities planning a line. Strong land use constraints are mainifested in the general tendency to bypass historic monuments, to avoid fragile ecologic areas, to preserve wilderness areas, natural areas and nature preserves, and to eliminate any potential danger of interference with points of congested transportation. Many hearing controversies and court actions have revolved around the question of esthetic compatibility between utility lines and their surroundings; the issues most frequently involve visual harmony, although the problem of noise also arises (e.g., electromagnetic noise interference with radio and TV reception as well as audible hum from power lines and the high decibel levels of pipeline booster stations).

In locating a line, means to mitigate the potential adverse impacts are available, particularly in regard to some environmental features. For example, visual impact can be reduced by use of vegetation for screening; by taking advantage of the topography to minimize both extent of visibility and its disharmony with the environment, and by appropriate selection from among technical options, such as structures and construction and maintenance practices. Esthetic principles can often be applied to minimize the potential incompatibility of a utility line with surrounding land uses; the objection to locating a line next to a residential or a scenic area may depend, to some extent, on the visual disharmony that the line creates. Concern as to the psychological impact of a line is, to a particularly large degree, a matter of how carefully the utility carries out its planning and preliminary preparation. In many communities through which a utility line passes, the potential of opposition and distress in terms of perceived effect on life-style may be alleviated (if not prevented) by cooperative efforts by the professional staff of the utility to acquaint the public with what is planned, to work harmoniously with local regulatory bodies and citizens' groups, and to create citizen participation in determining how the line will be routed. Much the same is true of potential impacts on community services. Unlike construction projects of the magnitude of a multi-megawatt power generating plant, which requires a construction force numbering as much as 2000 or more to be located in one spot for a matter of years, few utility lines will present a stress upon the capacity to provide educational and medical facilities or police and fire protection. Assurance that such matters have been considered and that cooperative efforts are under way to provide any temporary increase that may be required in capabilities should be adequate to obviate any real or anticipated problems.

There are necessarily some trade-offs involved among the social, economic and environmental factors, since not all desirable features can be realized simultaneously in all utility lines. Often, a choice must be made among land uses, each of which has some element of incompatibility. Running a line through a particular rural region may involve either some disruption of agriculture or disturbance of a wilderness area. The routing with the least incompatibility of land use must be based upon the relative value of land for agricultural purposes, in contrast with cultural and recreational purposes. Conflicting viewpoints also surface in the trade-off between concern for esthetics and for land use when a choice arises between routing a line within or adjacent to a highway (where its visibility is deemed objectionable to many viewers over a long distance) and placing it in a remote region where it is in discord with the current land uses and planned development of the region.

The factors discussed in this section are presented in four subsections. The first presents one possible classification of land uses and summarizes how the various categories of usage are likely to be affected by a utility line. Under esthetics, the next subsection discusses visual impact, particularly in terms of visibility of the line, scenic land features that influence both the potential for adverse impact and the opportunity to mitigate this problem, and design of lines available to minimize visual incompatibility of the line. In the third subsection, both audible sound and electromagnetic interference are considered. The last subsection discusses the possible impact that a line might have on community services such as schools, medical facilities, transportation and police and fire protection.

LAND USE

The feasibility of constructing a line and citizen acceptance of it are closely linked to the types of land use adjacent to the proposed line location. In considering the potential impact of a line in any specific location, both the present land use as well as what is planned for the future are important. In some situations, zoning regulations may pose a binding constraint; in others, they serve to designate the use of the land affected. In any case, the aid of local and regional planning agencies is invaluable in corridor siting studies. By working with existing planning agencies, a shared data base may be used, and integration of utility corridors into land use plans and policies may be assured.

In considering the impact that utility lines have on land use, it is important to keep in mind the fact that quantitatively, the amount of land denied to other purposes once a utility line is constructed is quite small. For pipelines, ROW width requirements during construction may be as much as 100 feet. The amount of space that must be kept cleared typically ranges between 10 and 25 feet (see Section VI) or a total not exceeding 3 acres per linear mile of line. Moreover, this stretch represents essentially open land (except for markers and occasional above-surface structures) that may, in many situations, be available for such recreational purposes as hiking and similar types of multiple use. ROW widths required for overhead transmission lines, while greater than for pipelines, are also small in terms of land use per mile of line. The area within the ROW is potentially available for other uses, except for the land occupied by the poles or towers that support the lines. Thus, where the ROW consists of easements across property, the greatest part of the area can continue to be used for its original purpose such as farming, grazing, etc. Where the ROW is acquired as fee ownership, multiple uses are often possible, as discussed in Section VII.

Table V-1 shows some typical requirements for total ROW area (in acres per mile) for each linear mile of a power line, as well as the approximate area occupied by each tower. (Estimates derived from BPA sources, largely from scale drawings of typical tower structures using average figures for number of towers per mile.) It may be seen that, for most voltage levels, a considerable portion of the ROW area is available for multiple use in a typical stretch of a power line.* It should be noted that Table V-1 is in no sense prescriptive, as ROW widths vary as a result of many factors. It is intended only to illustrate

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*At infrequent intervals, dead-end or other special support structures (see Section V) may require up to 12,000 square feet of base area. These and the occasional substations (see Section V for typical dimensions) slightly reduce the percentage of total area available. Similarly, valves, booster stations, and other aboveground structures (see Section VI) are required at infrequent intervals for pipelines.

TABLE V-1
POWER LINE ROW AVAILABLE FOR MULTIPLE USE

kV	SYSTEM TYPE (CIRCUITS)	MATERIAL	CONFIGURATION	ROW WIDTH (Feet)[1]	TOTAL ROW AREA (ACRES/MILE)	TOTAL TOWER AREA (sq.ft.)	ROW AREA AVAILABLE FOR OTHER USE (%)
115	Single or Double	Wood	H-frame (unguyed)	50-90	6-13	275	over 99
115	Single or Double	Wood	H-frame (guyed)	90	13	675	99
115	Single or Double	Wood	Single pole	50-90	6-13	100	99
115	Single or Double	Wood	Single pole (guyed)	90	13	300	99
230	Double	Metal	Tubular Pole	125	14-15	100	over 99
230	Single	Metal	Flat or delta	125	14-15	400	over 99
230	Double	Metal	Stack	125	14	1000	98
500	Single	Metal	Delta	125-160	15-19	900	99
500	Single	Metal	Flat	125-160	15-19	700	99
500	Double	Metal	Delta	125-160	15-19	1200	98
500	Double	Metal	Stack	125-160	15-19	1700	98
765	Single	Metal	Portal	180-220	21-26	3200	89-91

[1] See Section

Sources: Bonneville Power Administration: Environmental Statement, Fiscal Year 1975 Proposed Program, Facility Evaluation Appendix; Supplements to the Environmental Statement Fiscal Year 1976 Proposed Program: Lower Snake Grid Reinforcement, Pebble Springs - Marion 500-kV Line, Shelton-Kitsap 230-kV Line; General Construction and Maintenance Program; Working Document of Transmission Line Construction Characteristics.

It is important to emphasize that the widths given here are in no sense prescriptive. It is recognized that the widths for particular voltages may vary in different areas of the country as well as design features, and special conditions that may exist for a particular line. The figures in this table are intended to be representative only, and are provided for the purpose of illustrating rhe point that the greatest portion of a power line ROW is actually left free, as open space or for the possibility of other compatible uses.

the point that very little land is actually "consumed" by power lines.

COMPATIBILITY OF UTILITY LINES AND LAND USES

There are obviously many trade-offs involved in determining what land uses will be most compatible with a utility line in a specific situation. To a considerable extent, "compatibility" is subjective, depending on the point of view. Open land, for example, may be an attractive site for utility construction from the utility company and general public viewpoints, yet most farmers may tend to feel that some other land use might be more compatible. Although many government preserves offer the advantage of minimum disturbances to daily human activities, especially those of a commercial nature, conservationists usually regard the utility lines as intrusions incompatible with preservation of wilderness or other natural areas; and the suitability of parks, recreational areas and other public lands needs to be considered on an individual basis. To many segments of the public, a utility line seems less obstructive through industrial and commercial land, where large structures already exist, than through residential areas. Land devoted to special purposes with which the construction and operation of the utility line would be in danger of interfering may be regarded by those who own or manage the land as relatively unsuitable for a corridor that crosses the land in order to serve other points. Yet, extractive industries such as mining and quarrying, and institutional uses such as schools and hospitals, have their own requirements for energy and must be served by transmission lines.

In this connection, as with other aspects of land use, compatibility must depend upon the success of application of routing and construction techniques to avoid or mitigate interference with existing land use and other potential adverse impacts. The creation of additional open space by a skillfully planned utility line near an institution may be an advantage. Watersheds can be, and often are, crossed without damage by utilizing proper engineering methods. Although orchards are, in general, more likely to be interfered with by a power line than is cropland, in most instances, towers can be raised to a point where the corridor spans well over the trees.

In using recreational or conservational land, the environmental constraints discussed in Sections III and IV must be heeded and care taken to prevent significant alteration of the character of the land. For example, the Northern Border Pipeline (Ecology and Environment, Inc., 1974) explicitly sought to minimize the extent of encroachment on wetlands of the Dakotas and Minnesota and interference with the capacity for coldwater fishing in the streams of Illinois and Iowa. In the use of commercial and industrial land, important considerations include safety precautions (e.g., in regard to building clearances) and the prevention of interference with movement of personnel and equipment. In all such situations, the engineering costs of special measures that may be necessary must be balanced against the economic gains and costs of routing through other types of land use.

Additional problems in locating utility lines are a function of population density or developmental intensity. In urbanized areas, for example, utility line location is generally considered to be difficult and often undesirable due to the many obstacles that must be overcome. Because of the extensive existing development, the potential locations for shared corridors are limited. Very often, only land suitable for a narrow ROW is available. Thus, the availability of land within an urbanized area may become a crucial determinant for a shared corridor location, and practicality, esthetics, cost and ease of operation and maintenance may be relegated to a secondary consideration. ROW acquisition and development in an urban area may require the removal of structures or inhibit other urban construction and development, thus presenting a possible economic loss to the community. At the same time, land purchased in an urban area will generally be more costly for the utility company than land in a rural area. There are so many competing uses in an urban area on which a high real estate value is placed that land costs can represent an important constraint to locating lines in an urbanized region. Rural areas, in comparison with urban areas, exhibit fewer impediments to utility line placement. There are often fewer man-made constraints (such as buildings and roads) to limit the possible location of the corridor. Single ownership of large tracts of land generally renders land use arrangements for utility lines more easily obtainable. When constructing transmission lines, however, the creation of electromagnetic noise by transmission lines must be considered since television and radio transmission is generally weaker in rural areas and, therefore, more easily disrupted. Such interference can be minimized in all but a very few remote areas by utilizing technological improvement of line design, conductor size, ROW width and individual corrections. Suburban areas are generally characterized by development that is largely residential, less dense than urban areas, yet more dense than rural areas. As such, a combination of the considerations that affect lines both in urban and rural areas may be applicable to the suburbs.

The foregoing discussion indicates some of the reasons why generalizations about compatibility of utility lines with various land uses have been shown to be risky at best and oftentimes misleading. Few, if any, adjacent land uses are ideally compatible with utility lines. On the other hand, the difficulty in reconciling some types of land uses with utility lines seldom creates an exclusion criterion. Valid reasons for a specific line to cross land devoted to a particular usage in the face of unknown disadvantages may occur if it allows that more severe problems elsewhere be averted. In this context, Table V-2 is presented as a summary of some of the considerations affecting compatibility of utility lines with types of land use together with some possible methods of problem amelioration.

TABLE V-2

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Agricultural (crops, grazing, rangeland, timber, orchards)	Soil compaction and reduction of fertility for crop production. Hazards to livestock from accidentally ingesting scraps left from construction. Livestock may use towers as scratching posts, damaging the soil in thin crusted areas. Interruption of farming activities during construction and maintenance. Removal of trees from timberland and orchards.	Avoid cropland in favor of pastures, rangeland; in particular, avoid irrigated cropland. Ensure complete cleanup after construction.
Industrial	Hazards of combustible stored materials to line. Conflict between need for cleared space along ROW to facilitate maintenance and possible need for space to expand existing buildings. Impedence to trucking deliveries, employee movement, other activities. Transmission lines may pose hazards to buildings and clearance needs can conflict with building heights. High cost of land acquisition.	Locate ROW to avoid conflict with buildings, other industrial structures, and activities comprising or supporting industrial operations. Schedule construction and preventive maintenance for times of minimum potential conflict. Arrange for shared or joint use of ROW for purposes not interfering with line.

TABLE V-2 (Continued)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEMS AMELIORATION
Extractive Industries (mining, quarrying, etc.)	Interference with operation required for extraction, hauling, preprocessing. Possibility that extraction may undermine soil creating instability for structures and that heavy machinery can rupture pipelines, destroy tower footings.	Route line to avoid close proximity to extraction and supporting operations including hauling, delivery of supplies, etc.
Commercial	Possible interference with buildings, space requirements, commercial operations (deliveries, shipments, customer egress, etc.). Possible hazards to buildings and personnel, especially from transmission lines. Adverse esthetic impact, tending to discourage customers.	Locate actual ROW to avoid interference Ensure safety standards for clearance, ROW widths, grounding, Miltiple ROW use to provide additional "green" space improving esthetics, extra parking space, other amenities.
Residential	Noise (construction; operation of pumping, booster stations; electromagnetic interference). Concern over safety factors. Adverse esthetic impact. Radio/TV interference from lines of 500 kV and above.	Locate actual ROW at maximum distance from dwelling unit (300 feet to avoid interference). Place noisy operational units in nonresidential zone. Follow clearance, grounding, other safety requirements.

TABLE V-2 (Continued)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Residential (cont.)		Place line at rear of dwelling units instead of front or side. Avoid location near individual family units, owner-occupied property. Follow subdivision and development boundaries to avoid dividing neighborhoods. Avoid bisecting property by following property boundaries. Provide multiple use of ROW with recreation space, other amenities.
Recreational	Intrustion into hunting areas can disturb game, be accompanied by restrictions on hunting activity. Construction activity can damage wetlands, degrade water qulaity, interfere with fishing. In areas of intensive recreational activity, massive structures can appear as intrusions into limited space available. Possible hazards, especially from transmission lines, in playgrounds or other areas where metal objects are prominent.	Clear so as to provide open space adjacent to wooded areas for wildlife nesting and breeding. Avoid cutting across wildlife migration paths or disturbing breeding areas. Avoid wetlands, any especially sensitive ecologic areas. Try to span small recreational areas as much as possible; locate necessary structures unobtrusively.

TABLE V-2 (Continued)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Recreational (cont.)		Ensure adequate grounding, other safety precautions. Use ROW placement techniques available to reduce adverse esthetic impact. Cultivate new multiple uses on ROW in recreational land.
Conservation	Disruption of ecology; disturbance of wildlife, hazard to rare and endangered species. Esthetic impact of intrusion in wilderness areas.	Avoid ecologically fragile areas; avoid habitats, especially nesting and breeding grounds, of rare or endangered species; follow clearing practices that provide combination of open and wooded spaces to favor wildlife. Reduce visibility of ROW and structures by selective cutting, use of vegetation and topography for screening, simple unobtusive stuctural design. Limit use of access roads by off-the-road vehicles.

TABLE V-2 (Continued)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Transportation and Service	Federal Highway Administration restrictions on use of Interstate Route ROW. Increased visible exposure of overhead structures adjacent to frequently traveled highway. Electrical interference with railway communications signaling equipment, hazard of inductance in rails; costly shielding requirements. Circuitous route imposed on utility line in following transportation ROW in hilly terrain. Interference of transmission towers with and hazard from aircraft near airfield. Possible interference with or hazard to traffic during construction.	Follow esthetic guidelines to minimize visual intrusiveness and incompatibility of overhead structures especially transmission line. Provid shielding requirements if necessary to share railroad ROW. Select as far as possible less heavily traveled routes (highway, railroad) where frequency of observation, potential interference will be less. Avoid aircraft takeoff, landing, fly way areas.
Special Use (Landmarks--historical, cultural scientific, and scenic)	Esthetic incompatibility (especially of overhead structures). Disruption of disturbance of significant features, especially during construction.	Avoid historic and scenic monuments where towers, transmission lines, any other aboveground structures would be discordant.

TABLE V-2 (Continued)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Special Use (cont.)		Avoid areas (e.g., paleontologic sites, other geologic points of interest, old structures) where disturbance of soil, other construction and maintenance activities would endanger the landmarks. Follow guidelines to minimize visual intrusiveness.
Religious and Other Institutional (schools, hospitals, etc.)	High price of and difficulty of acquiring land. Esthetic incompatibility (construction and operational noise, visual disharmony). Limited land may make it difficult to locate at adequate distance from buildings and activities that will be interfered with and reduce space available for institutional purposes. Possible hazards to concentrations of personnel who may be relatively helpless if accident to line occurs (e.g., young children, patients)	If essential to use such land, consider only those institutions with sufficient land to provide adequate separation. Ensure all safety precautions fully met. Follow esthetic guidelines to use topography and vegetation as screening to reduce visual impact. Avoid locating noisy facilities (e.g., booster stations) within audible range.

TABLE V-2 (Continued)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Governement (not elsewhere included)	On military reservations, utility (especially transmission line) could interfere with maneuvers, interact on a mutually hazardous basis with maneuvers, construction, operations of aircraft, communications. Same for research and test facilities.	If necessary to use, ensure line is placed in a reserve area safe from mutual interference, well mapped and posted to prevent accidents. Ensure adequate clearance from buildings, sufficient distance to avoid interference with egress by personnel. Follow guidelines to minimize adverse esthetic impact.
Domestic and Municipal Watersheds (including reservoirs)	Possible disruption of hydrologic system providing water supply. Danger of contamination or deterioration of water quality.	Avoid reservoirs (where these are not the source of hydroelectric power generation). Ensure that danger of erosion, siltation, contamination or diversion of ground and surface water will be minimal; is specific locations where such dangers are minimal cannot be found, avoid altogether. Avoid slopes, soil of high erodibility, places with high water table, etc., and follow construction practices to minimize disturbance.

TABLE V-2 (Concluded)

ABILITY OF VARIOUS LAND USES TO ACCOMMODATE UTILITY LINES

LAND USE	CONSIDERATIONS AND PROBLEMS	PROBLEM AMELIORATION
Water Bodies	Engineering difficulties and construction cost. Sedimentation from construction and maintenance activities creating hazard to marine life. Possibility that transmission structures of over-water pipelines may impede navigation. In areas of high turbidity, pipelines may have tendency to shift position or sand may be abrasive to pipe. High visual impact of over-water systems. Little effect on water systems once construction is completed. Corrosion potential may be high.	Assure suffiencient vertical and horizontal clearance. Weight pipelines in areas of high turbidity. Locate in areas of slower water movement. Location through water bodies originally of lower quality will have less impact than on undisturbed, clean water.
Undeveloped	Minimum impact on land usage but barren or lightly vegetated areas are easily eroded and scarred by construction.	Use helicopters where soil or ecology is fragile to minimize access roads and disturbance of surface.

Compatibility of land use is also closely associated with acceptable multiple uses of a ROW (specifically considered in Section VII). Activities permitted on an actual ROW tend to imply compatibility of adjacent land for uses involving those same activities.

LOCAL ATTITUDES AND VALUES

Beyond the problems and considerations associated with land use by type and developmental density, compatibility of a utility corridor with the various land uses must ultimately be established by considering local attitudes and values.

Complex systems of weighting factors assigned according to questionnaire returns and other forms of public response have been developed to measure public land use values. In an attempt to simplify the ranking process, changed land values have been proposed to indicate the impact of utility lines on a given category of land use. For instance, residential land value is sometimes considered to decrease (primarily due to esthetics), and agricultural land values may decrease if agricultural activities are limited by the corridor.

It should be stressed that no absolute ranking of land use in order of compatibility is affected by local and regional considerations that may make agricultural land more important in one situation and recreational land more significant in another; in turn, these considerations reflect such variables as the economy and life-style of the region, as well as the relative scarcity of land available for different uses.

The various types of land use differ as to their compabitility with utility lines according to the criteria applied. For example, in a transmission line study for the BPA using PERMITS (Landscapes Limited, 1972), land uses were considered in relationship to the overall type of development in a given locality. In that study, different criteria were applied to urban and agricultural areas. An example of the relative ranking by PERMITS of utility line impacts on various land uses according to the criterion of "Minimization of Disruption to Existing Urbanized Land Uses and Human Settlement" follows, ordered from greatest impact (least compatible) to least impact (most compatible):

--High Density Residential
--Medium Density Residential
—Commercial - Aggregated
--Suburban Residential
—Recreation Residential
—Public/Semi-public
--Rural - Farm Residential, Rural Non-farm Residential
--Commercial - Isolated
—Industrial - Heavy, Industrial - Light, Extractive

Because it is unlikely that agricultural land use would occur in an urban area, it was not included in the above list of factors. However, "Minimization of Disruption to Agricultural Land Use Practices" was also used as a criterion and, in this instance, only agricultural land use categories were included.

The perceived impact of a utility line upon land use may differ in relationship to local land use attitudes and values. These differences were reflected in the weighting assigned to factors in the PERMITS study. For example, using the agricultural criterion given above, it was determined that for one possible route (Transect A), transmission line impact would, in descending order of impact, affect Research Farms, Field Crops and, finally, Livestock. In contrast, it was determined that for an alternate route (Transect B) through a different locality, Field Crops would suffer the greatest impact, and Research Farming the least.

EFFECTS OF UTILITY LINES ON GROWTH AND LAND VALUES

Except in the instance of above ground pipeline location, it is unlikely that a completed utility line would seriously impede circulation routes or population expansion. In actuality, the placement of power lines and particularly substations and natural gas pipeline terminals may generate new population growth by making utilities easily available for use by new developments.

It is possible that the opposition directed toward utility line location may be created more by the fear of change than by the actual impact. For instance, a utility line through an established residential area may be adamantly opposed because of the fear that there will be a great deal of negative esthetic impact or that the neighborhood unity and land values may be destroyed. However, there is little clear evidence to indicate that a utility corridor actually decreases land values. In most situations, residential land can be shown to command a higher price within a few years than was paid by owners who purchased before a utility line was installed. Although some home owners may move out of an established area after a line goes through the area, there is an absence of documentation to substantiate the idea that prospective purchasers either of the existing homes or in a new development are discouraged by the presence of a utility line.

One incident in particular seems to indicate that actual esthetic impact may not be as great as is feared. After publicizing an offer to furnish various types of vegetative cover, free of charge, to replace trees removed during construction, the Kansas Power Company had no citizen requests for revegetation in over three years of making this offer available (McCrackin, 1974). The possibility exists that after a utility line has been constructed, new residents may ironically prefer homes adjacent to a utility ROW because of the additional open space available for gardening and recreation or, in instances where the ROW has been revegetated, residents may find that the green space acts as a buffer zone between properties.

ESTHETICS

Until the 1960's, the esthetic impact of utility corridors was rarely considered. Land was considered a dispensible commodity, subject and submissive to the technological needs of man. With the increasing realization that our land is not unlimited came a new appreciation of esthetics in the wise usage of this restricted resource.

Visual Effect

The esthetic impact of any visual change in the environment will always involve subjective judgment. This fact is evidenced by such events as the occasional costly law suit intended to prevent construction of a house regarded by the plaintiff as "not fitting," although the defendant has paid a handsome sum to have it designed as "a thing of beauty." However, a few general criteria commonly applied in assessing the impact of a utility line will now be discussed. For instance, a poorly placed line may be viewed as creating a sense of discord due to visual incompatibility. Utility lines can detract from other landscape with the intrusion of cleared space and man-made structures. The width of shared utility corridors and of their above-ground structure is such that their presence cannot be hidden and may be deemed obtrusive. In particular, the size and rigid verticality of a transmission tower tends to visually dominate a house, storefront, or farmyard. Nevertheless, when placed with sensitivity, a shared corridor or utility line ROW may harmonize rather than conflict with the quality of the land.

In regard to the visual effects, both the visual quality of the landscape in which the utility line is to be placed and the magnitude of the resulting impact on the viewers need to be considered. Visual quality, the more subjective aspect, is particularly hard to assess; some recent studies, however, have yielded interesting results in terms of viewers' reactions and the characteristics of the setting of the utility line associated with the response.

The second aspect is more easily measured. Factors that can be and have been qualified for the purpose include:

- The number of viewers exposed to the line or corridor.
- Man-hours of exposure.
- Linear difference over which any segment of the line dominates from a specified viewing point so as to attract attention to itself, apart from the landscape.

- Distance from the viewer to the line.

- Extent or percentage of viewscape dominated by the line.

While the above means of quantification are particularly useful for comparing alternative locations for a line, they take neither the total visual impact nor the visual quality of the land into account. The subjective quality of esthetics makes precise quantification of these aspects impossible. However, methods for assessing visual impact have been developed and applied at least experimentally, including those discussed in the subsections immediately below.

Questionnaire to Determine Public Attitudes

Various questionnaires have been created to provide a vehicle for measuring public opinion or sensitivity toward the visual impacts of a proposed ROW. Most of the questionnaires, including those of Ontario Hydro (1974) and the Northern States Power Company (1974), depended upon the use of photographs to convey images to the respondent.

Although public input is an important element of ROW placement, it cannot be a self-sufficient or sole determinant for decisions concerning actual ROW placement. Questionnaires may be a valid indicator of possible social and cultural effects of a ROW, but not all of the public can be expected to understand all of the economic, technical or ecological effects of their ROW preferences.

Table V-3 presents the pertinent aspects of a survey administered by the Northern States Power Company in the summer of 1974 to residents of a rural Wisconsin farming region being considered for ROW construction. The results of the questionnaire have not yet been analyzed by the Northern States Power Company.

Evaluation of Visual Disruption

Typical of the techniques available to evaluate visual impacts is the "Landscape Image" disruption evaluation developed by Ontario Hydro to determine the visual impact of transmission lines. This impact is defined as "predicted disruption to the existing image of the area caused by a proposed development" (Vaughn, 1974). In using this methodology, the following steps are taken in order to produce a corridor suitability map:

a. Visual characteristics of each landscape unit within the study area are determined, and changes in visual character that would occur with ROW and tower construction are evaluated.

b. Areas of increased viewer sensitivity or visual awareness are identified for travelers and for residents (who are sent questionnaires for landmark identification). These sensitivity areas are marked as high-impact areas.

TABLE V-3

SUMMARY OF SURVEY BY NORTHERN STATES POWER COMPANY (1974)

TOPICS INCLUDED IN SURVEY	INFORMATION OBTAINED
Presentation of photographs	Preference rating of various steel and wood tower impact on land and respondent's preference for tower location
General effects of route location	Attitudes of the effect of ROW construction on land uses, visual esthetics, and land value as perceived by respondent (not necessarily for his own property)
Routing location preferences and effects on respondent's land	Attitudes toward the effects of ROW on present and future land uses, esthetics and economic value of land as perceived by respondent for his own property
Compensation suggestions	Means of determining compensation and effects of compensation on respondent's attitude toward route location as suggested by respondent
Control data	Age, education, sex, length of residency, occupation, special interest group affiliation, type of farming and acreage, future land use intentions of the respondent

c. The intensity of use of roads, railroad lines, and paths with viewscapes of the ROW are evaluated to determine the number of viewers exposed to the corridor and, thus, to establish areas of high sensitivity.

d. Potential screening devices or means of concealment are evaluated and mapped.

e. Future land uses and probable visual impact are evaluated and mapped.

f. The overlay maps (produced from the above steps) are combined to produce a final suitability map. Each of the individual maps may contain a constraint rating based on a maximum of 3 levels. Combinations of area scores are used to determine areas of highest to lowest level compatibility.

This system may be used for selecting and evaluating routes of minimum visual description within a given area, but cannot quantify the severity level of the "minimum visual disruption." Clearly, problems in application of the methodology include difficulty of explaining the constraint ratings to the public and the degree of subjectivity necessarily involved in setting criteria for scoring visual compatibility.

Evaluation of Visual Quality

A visual quality and impact evaluation methodology was developed by Jones with Battelle-Northwest (1974) to allow comparison between a range of alternatives for locating a transmission line within a specific landscape. This methodology is both a complicated and a comprehensive approach, producing a visual quality analysis for any given viewscape. The methodology proceeds as follows:

a. Landscape types (based on classes of landform and on land cover pattern) are mapped and rated for their ability to absorb transmission facilities without suffering major esthetic damage. Scarce and visually fragile landscape areas are identified.

b. To determine sensitivity of an area to transiting and residential viewers, viewsheds of major roads are mapped. Questionnaires are sent to residents of the potentially affected areas to determine preferred local environments. Factors that may alleviate visual impact, such as screening, tower designs and future land uses are considered.

c. All information from steps a and b is integrated on a single map, Possible corridors are then mapped. Viewpoints are selected and the visual quality of views from these points are determined "before" and "after" the construction of the transmission line, through the use of color photographs of existing landscape as well as photographs with an artist's rendition of the proposed transmission line. Evaluation of visual quality made by at least five evaluators is suggested by this methodology. These persons record their visual evaluations on a questionnaire provided for the purpose.

d. Evaluator's responses to intactness, vividness, and unity are combined to produce a total visual quality rating for a given viewscape as:

$$VQ = 1/3\ (I+V+U)$$

where:

VQ = visual quality of the viewscape

I = intactness of scene, --i.e., the apparent degree of natural condition as a function of human encroachment. For instance, natural landscapes may have the highest degree of intactness and urbanized areas, the lowest.

V = vividness of scene. Elements requiring special consideration include sharpness of skyline boundary definition, sense of spatial enclosure, scenes of extreme topographic relief, contrasting vegetation (i.e., falls, solitary tree groupings), water, sky and man-made elements.

U = measure of intercompatibility of a scene's components in forming a harmonious visual unit. Intercompatibility is achieved by a similarity of form, line, color, and texture, or a balance between contrasting elements.

For greater accuracy, visual quality attributes for intactness and vividness may be applied to each major viewscape element such as sky, landform, vegetation, waterform or man-made elements. The interested reader is referred to Battelle (1974) for further details.

It should be noted that neither these nor other methodologies documented for analyzing visual quality attempt to resolve conflicting public viewpoints. The extent that dominant preferences can be derived from questionnaires and that evaluators chosen adequately reflect prevailing tastes largely influence how successful application of the technique will be in predicting a consensus of opinion of the esthetic impact of the line.

Placement of Right-of-Way

In placing the ROW within a conceptual corridor (one that is 1/2 to 10 miles wide) and implementing the structures, a number of methodologies and guidelines have been developed to minimize the potentially adverse visual impact.

Photogrammetry for Clearing of Forested Areas

Photogrammetry (land surveys done through aerial photography) is used by BPA to delinate right-of-way clearing limits through wooded areas and to identify individual trees on the ROW that could possibly be left standing. This method is particularly useful to minimize the amount of clearing required. However, the expense involved in this procedure may limit the utility company's ability to provide photogrammetric analysis. With this method, a land survey taken from the ground is performed to provide necessary data used to determine the possible area to be cleared. In dense forests where the ground is obscured, cross sections must be taken by the ground survey party at each 100-foot station. In open forests, this is not necessary.

Through the use of stereoscopic photographs produced by photogrammetry, it is then possible to identify those trees that should be cleared. A tree-to-conductor clearance (rather than a tree-to-centerline clearance) should be used to vary the ROW width. Using this method, both a minimum clearance, where the duration of proximity of a tree to a conductor is short, and a greater clearance area, where the proximity is sustained, should be used. For instance, a falling tree would be in the proximity of the conductor for only a few moments, whereas a tree growing under a line may be there for at least one season. The temporary clearance needed for a falling tree and a 115-kV line may only be 3 feet, whereas permanent clearance between the conductor and a tree growing under the wire should be at least 10 feet.

Use of the photogrammetric method of clearing may require more engineering time than if a clear-cut straight-edged ROW were to be used. However, a significant saving in acreage of timber removal will, according to the experience of the Bonneville Power Administration, more than compensate for the additional engineering manpower. Reliability will equal that of the clear-cut method, although more maintenance will be required after the initial 15-year growth period.

Important individual guidelines for implementation of a ROW, especially one for an overhead transmission line, are presented below under the headings of topography, land units (including buildings, vegetation and existing ROW), and the structures. Even though only transmission lines are thought of as visual intrusion because of the towers, pipelines can be equally obtrusive due to cleared corridors, especially in areas of high canopied trees.

Topography

In placing a utility right-of-way, it is preferable to work with, rather than against, the contours of the land. Most of the following considerations have been abstracted from current Federal guidelines (U.S. Department of the Interior, 1970, Johnson, Johnson and Roy, 1970, Working Committee on Utilities, 1968). Each consideration is accompanied by figures, usually contrasting visually discordant and harmonious practices.

a. Locate the right-of-way to conform with topographic direction or patterns. Alignment counter to basic land orientation will call attention to the ROW as an alien element (Figure V-1).

b. Avoid crossing hills at right angles so the apparent width of the ROW clearing will be decreased. An oblique angle is preferable to crossing a hill top (Figure V-2).

c. Avoid centering alignment across hill crests or across valleys. The centering of lines on a symmetrical form serves to focus attention on them (Figure V-3).

d. Avoid crossing hills at crests so that the ROW clearing will not be silhouetted against the sky. Whenever possible, cross at a dip (Figure V-4).

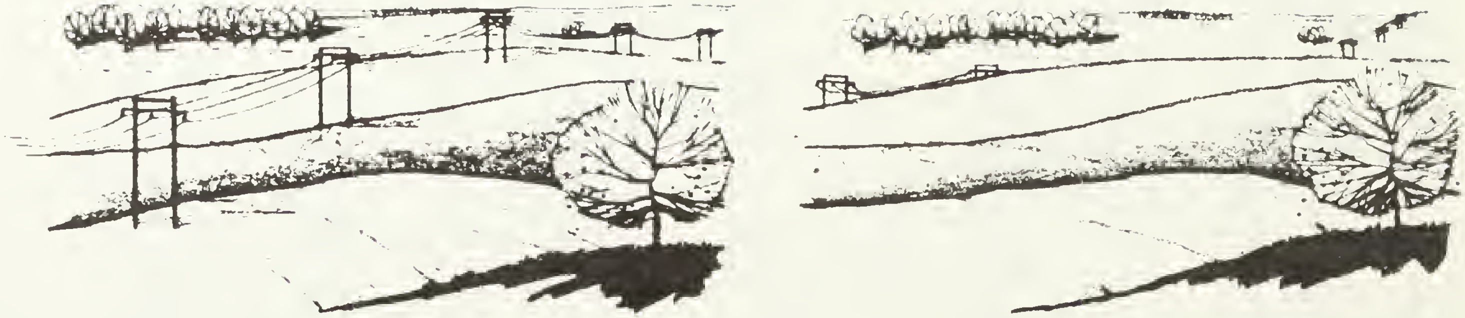
e. Right-of-way alignment should change continuously with changes in the topography by curving around mountains rather than traversing them in a straight line, so that the natural rhythm of the topography will not be disturbed (Figure V-5).

f. Use hills and mountains as a background to camouflage transmission lines (Figure V-6) as they provide a darker, more favorable, background than does the sky.

g. When crossing a roadway between canyon walls or in a cut between steep banks, lines should cross upslope of roads to minimize eye-level viewing for travelers (Figure V-7).

h. When crossing a canyon in a forest, high, long-span towers should be used to keep the conductors above the trees and to minimize the need to clear all vegetation from below the lines (Figure V-8). Clearing in any canyon should be limited to that which is necessary to string the conductors.

i. Avoid center alignment of rights-of-way through valleys, which are generally a focal point (Figure V-9).



POOR EXAMPLE

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FIGURE V-1

USE OF TOPOGRAPHIC PATTERNS IN TRANSMISSION LINE LOCATION

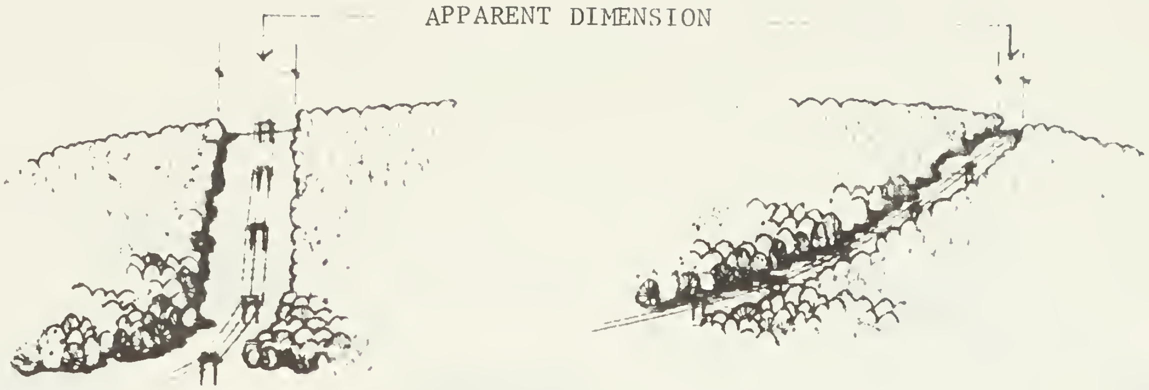

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FIGURE V-2

UTILITY LINE CROSSING ANGLES

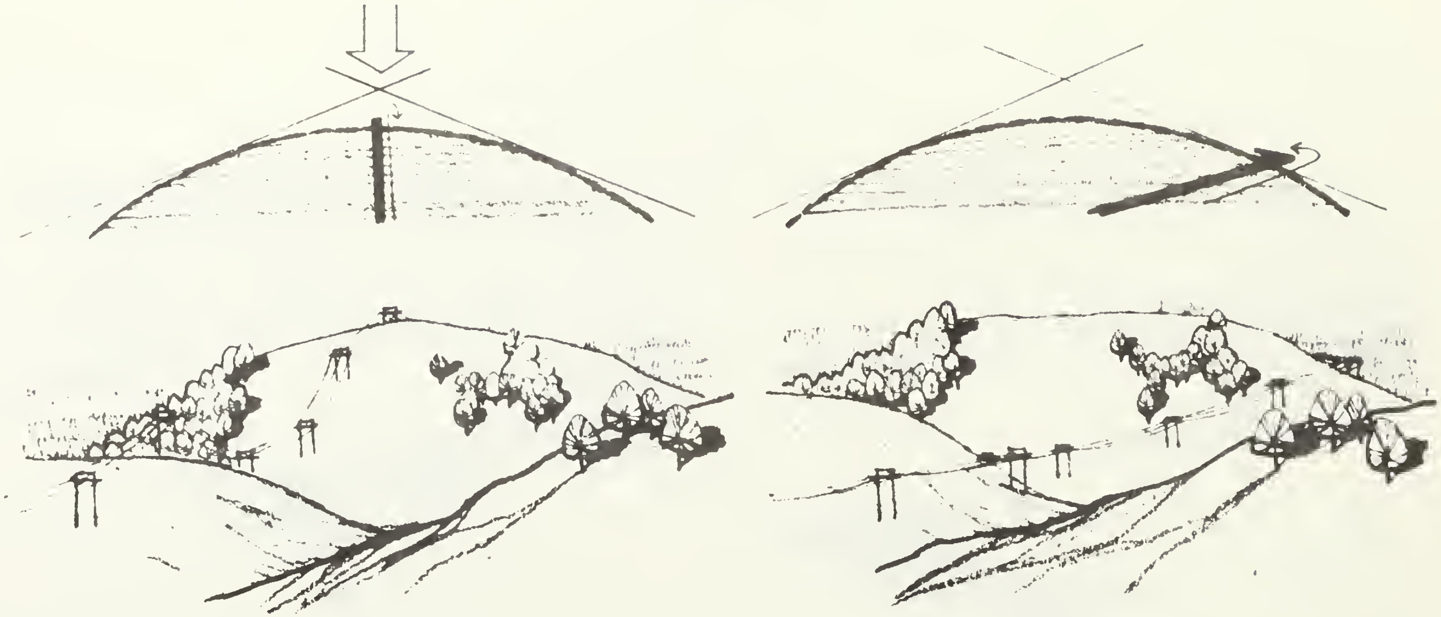

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FIGURE V-3

CONTOURS OF CROSSING FOR UTILITY LINES

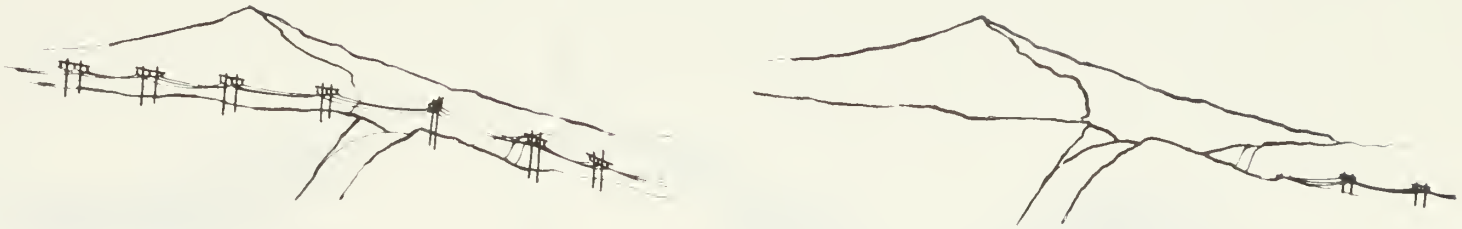

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FIGURE V-4

USE OF CRESTS IN UTILITY LINE LOCATION

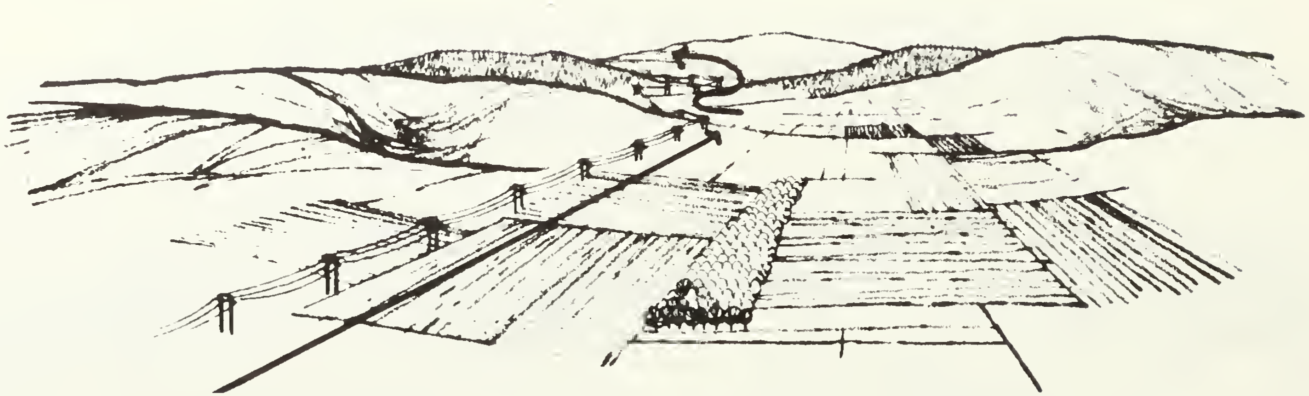
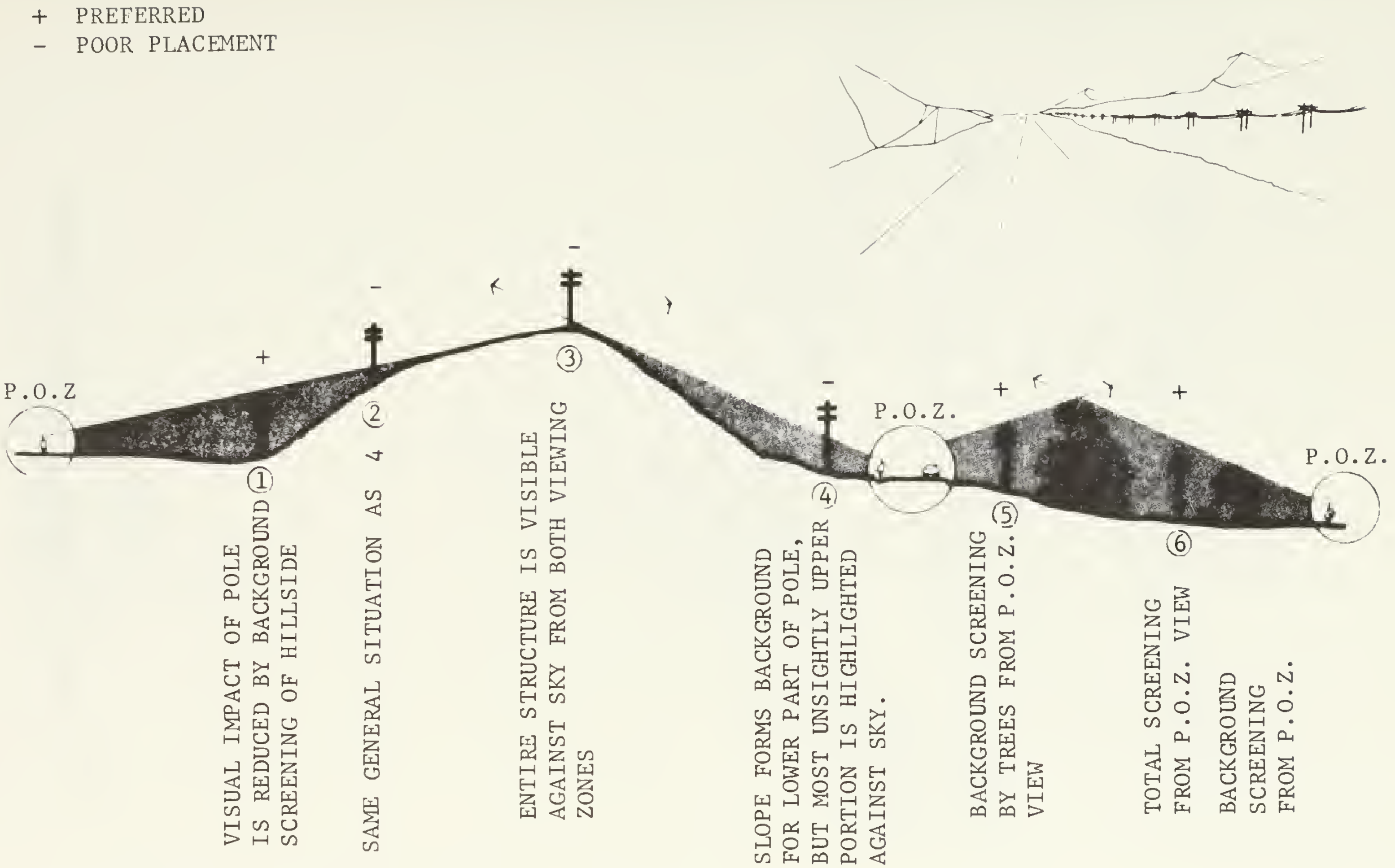


FIGURE V-5

CONTINUOUS CHANGE OF UTILITY LINE ALIGNMENT


+ PREFERRED
- POOR PLACEMENT
P.O.Z
P.O.Z.
P.O.Z.
+
-
-
-
+
+
+
①
VISUAL IMPACT OF POLE IS REDUCED BY BACKGROUND SCREENING OF HILLSIDE
②
SAME GENERAL SITUATION AS 4
③
ENTIRE STRUCTURE IS VISIBLE AGAINST SKY FROM BOTH VIEWING ZONES
④
SLOPE FORMS BACKGROUND FOR LOWER PART OF POLE, BUT MOST UNSIGHTLY UPPER PORTION IS HIGHLIGHTED AGAINST SKY.
⑤
BACKGROUND SCREENING BY TREES FROM P.O.Z. VIEW
⑥
TOTAL SCREENING FROM P.O.Z. VIEW
BACKGROUND SCREENING FROM P.O.Z.

P.O.Z. = Primary Observation Zone

FIGURE V-6

USE OF TERRAIN AS BACKGROUND IN UTILITY LINE PLACEMENT

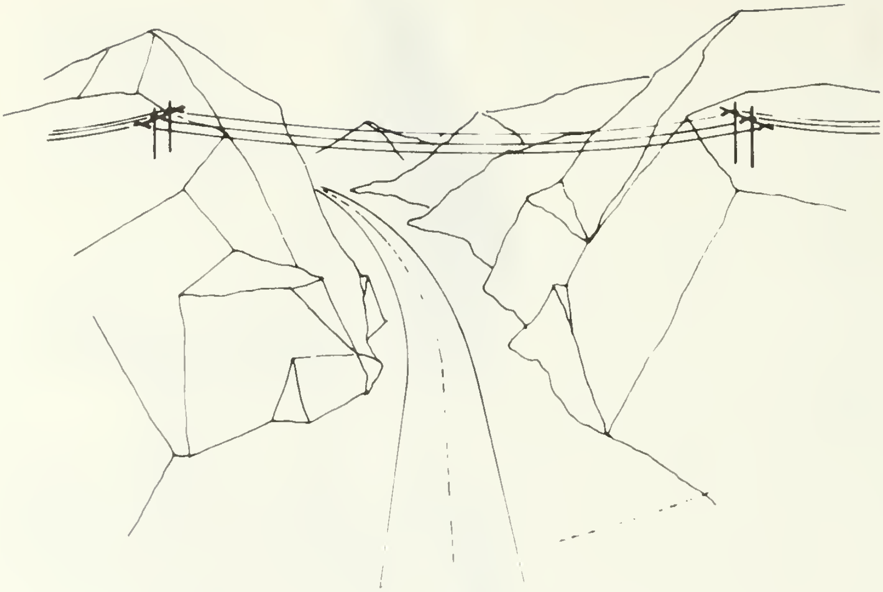


FIGURE V-7

EFFECTIVE UPSLOPE ROAD CROSSING TO MINIMIZE VISUAL IMPACT

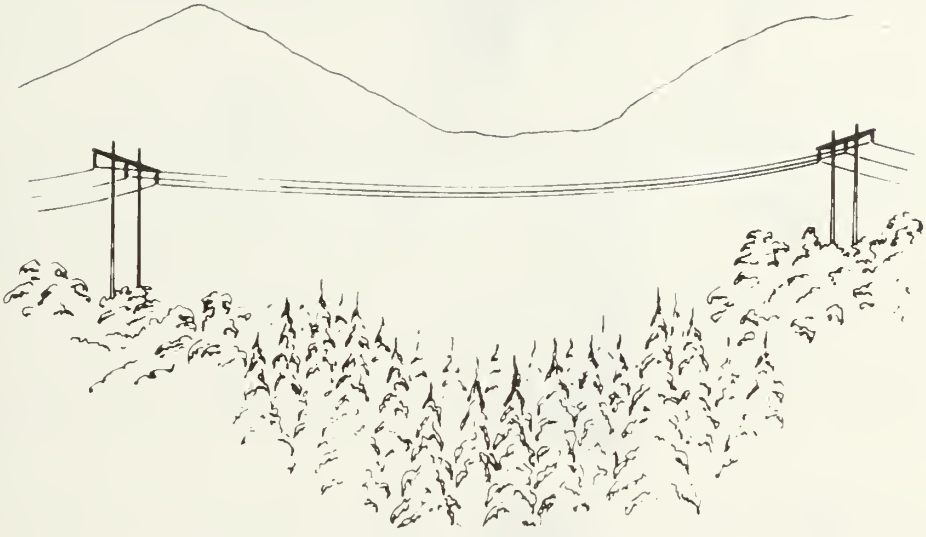
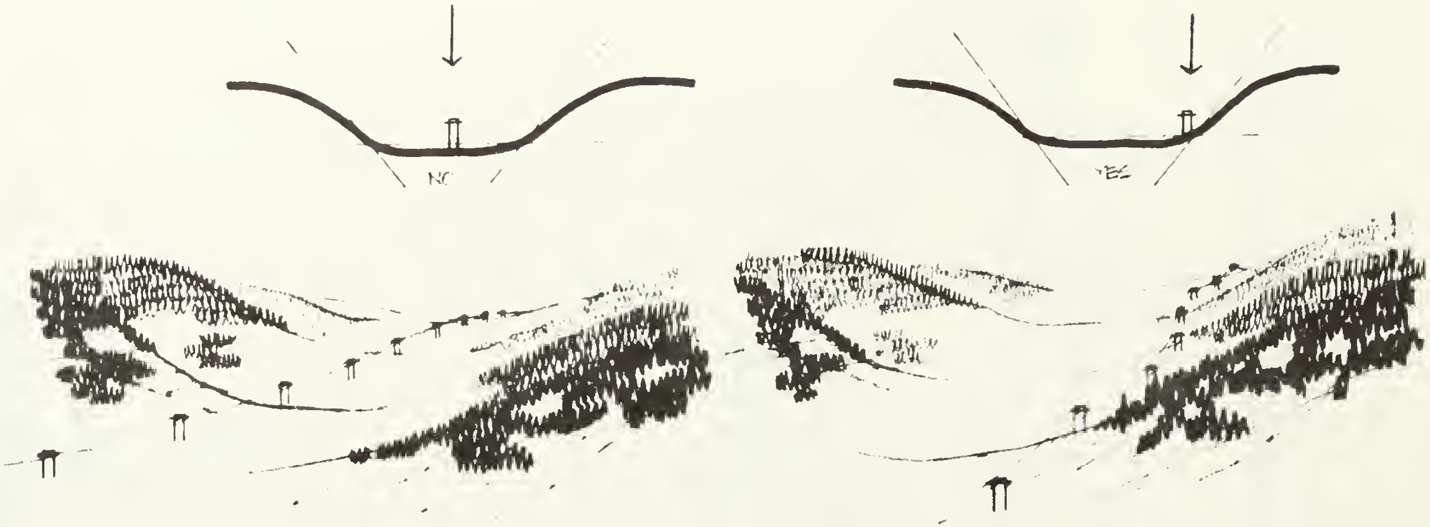


FIGURE V-8

EFFECTIVE TRANSMISSION LINE CROSSING
OF CANYON IN FOREST



POOR EXAMPLE

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FIGURE V-9

EFFECTIVE UTILITY LINE PLACEMENT
IN A VALLEY

j. Avoid ROW water crossings at highpoints that may be seen from great distances down the waterway.

k. Avoid paralleling a waterway so that the ROW will not dominate the viewscape for great distances.

l. When crossing plains, follow straight right-of-way alignment to avoid attracting more attention to the line or clearing.

Land Units

In placing a utility right-of-way, it is preferable to consider patterns already imposed upon the land by types of land cover and development. In this way, the cohesiveness of various land units defined by similar visual characteristics may be maintained. The following guidelines are useful in considering land unity:

a. Right-of-way placement is generally best along the periphery of a land unit or between land uses. It is best to follow existing barriers, such as edges of woods or fields, and fences, rather than to create new land divisions because of right-of-way access and clearance requirements (Figure V-10).

b. When crossing a roadway, jog alignment to avoid long views down the ROW (Figure V-11). It should be noted, however, that angular crossings, such as indicated in Figure IV-11, can be quite expensive with high voltage lines.

c. Avoid crossing at the high points in the road so that towers cannot be seen from great distances. Instead, cross between two high points or at a dip or curve in the road (Figure V-12).

d. In placing transmission lines, use a long span so that a planted screen may be used adjacent to the highway, thus obstructing the view down the ROW (Figure V-13). The visual advantage of such a span must be balanced, however, against the possibility of a more severe impact because of the high towers required.

e. When crossing a roadway that is adjacent to hills, mountains, or rock formations, whenever possible, approach and cross diagonally, thus preventing long views down the ROW (Figure V-14). However, the number of angles required in this type of crossing can be very expensive. Therefore, such a crossing is recommended only when other measures to mitigate adverse visual impact cannot be accomplished.

f. At road crossings, the use of multiple-circuit transmission towers may be effective in minimizing the impact of lines at that point (Figure V-15).

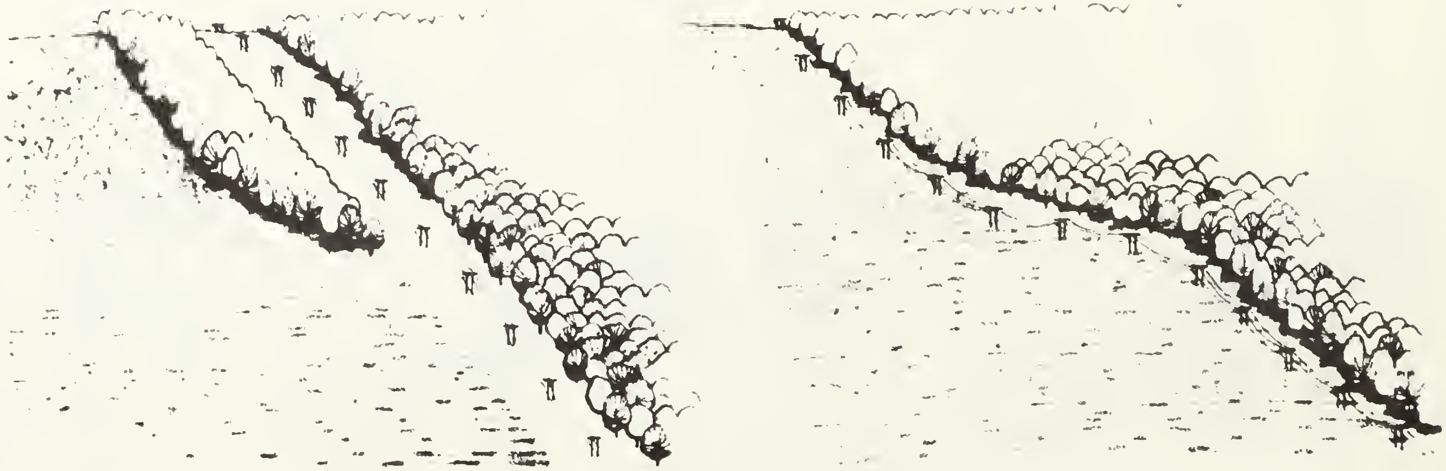

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FIGURE V-10

USE OF EXISTING DIVISIONS IN UTILITY LINE PLACEMENT

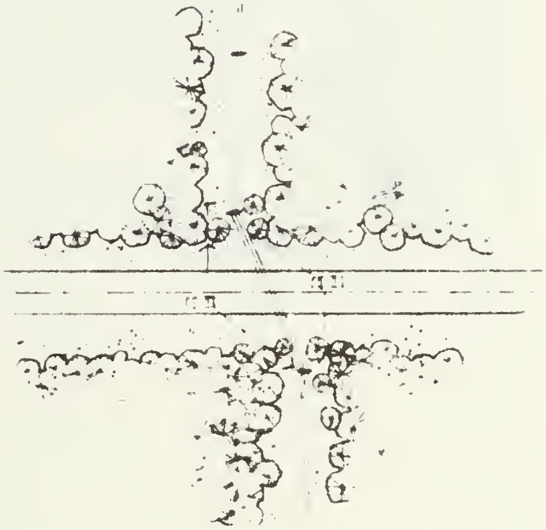

FIGURE V-11

JOGGING UTILITY LINE ALIGNMENT AT ROAD CROSSING

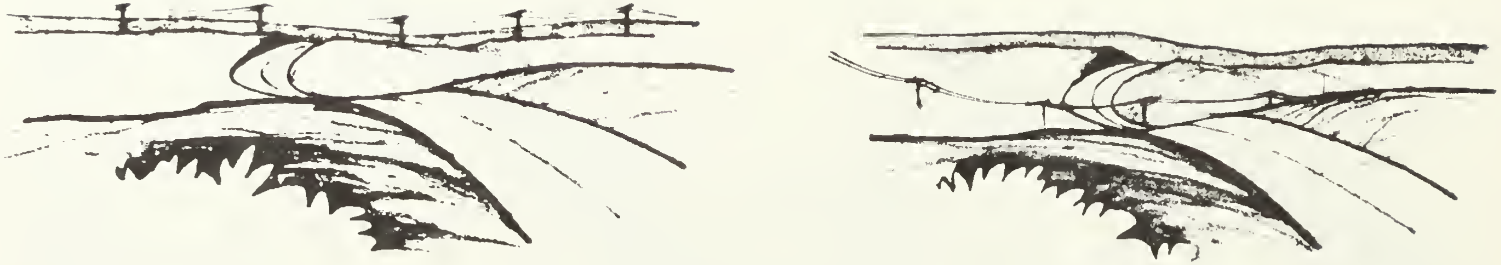

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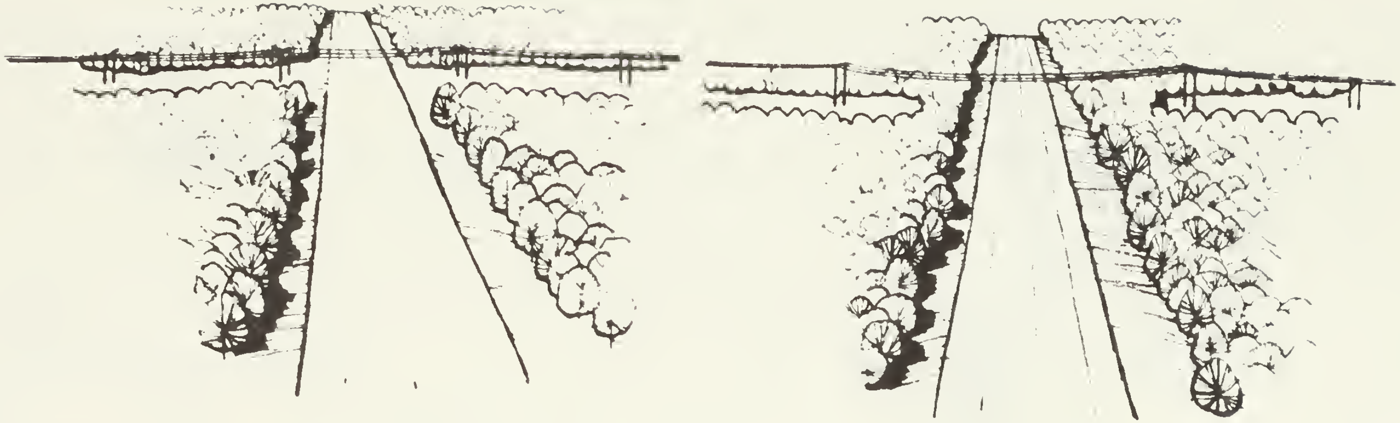
FIGURE V-12

USE OF TOPOGRAPHY TO MITIGATE UTILITY LINE
VISUAL IMPACT AT ROAD CROSSING



POOR EXAMPLE
(Short Span)

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(Long Span)

FIGURE V-13

USE OF PLANTED SCREEN AND SPAN AT UTILITY LINE ROAD CROSSING

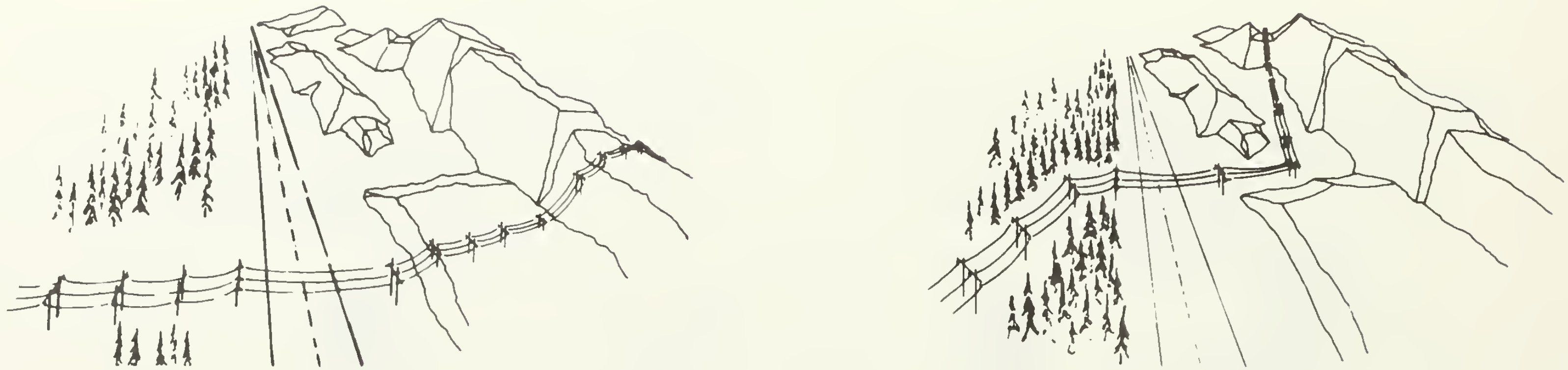

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FIGURE V-14

APPROACH AND CROSSING OF ROADS BY UTILITY LINES
IN HILLY TERRAIN

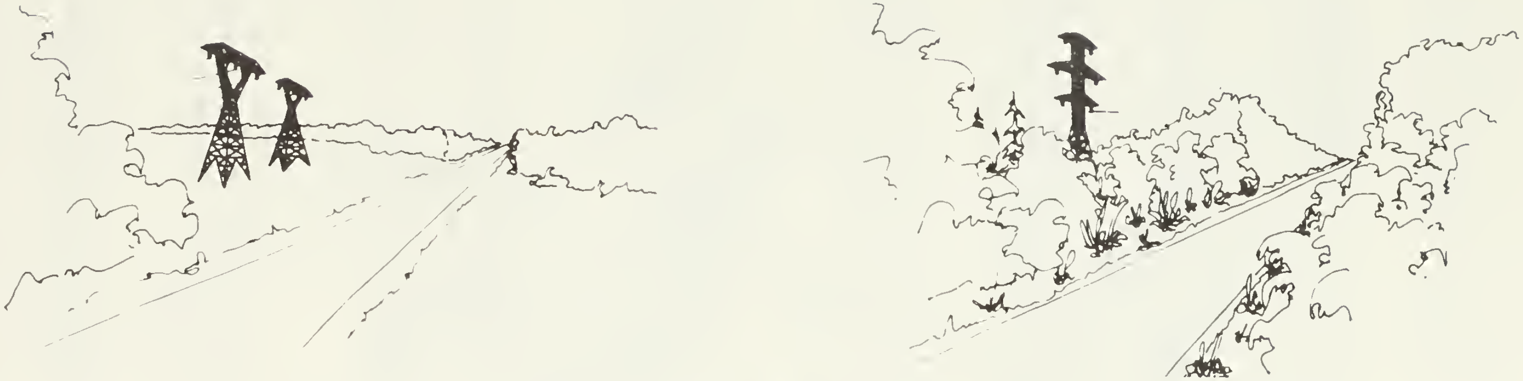

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FIGURE V-15

USE OF TOWERS FOR MULTIPLE-CIRCUIT TRANSMISSION LINES
AT ROAD CROSSINGS

g. Avoid transmission line crossings of major roads near or at intersections or interchanges to prevent dangerous obstruction of view from oncoming cars.

h. Avoid close proximity to buildings. Relative heights of the buildings and the tower will be mentally compared by the observer with the result that tower height is accentuated to an undesirable degree.

i. Complex landscapes (such as scattered, somewhat open, wooded areas with a variety of visual elements) are generally more capable of absorbing an additional element than are landscapes that are simple and uniform.

j. It is best to locate new construction on existing ROWs. If unlike anything else in the neighborhood, the potential impact of a new feature will be greater than if it is an addition to what is in existence.

k. Single towers are preferable to pairs because less ROW width and less structural surface area will be required. If pairs of towers are necessary, however, they should be placed next to each other to minimize ROW width (Figure V-16).

l. Avoid straight ROW alignment through woods or vegetated landscapes. A change of ROW alignment will allow views down the ROW for only a limited distance (Figure V-17); however, a number of angle structures for the transmission line route through the forest may be very costly. Often, the same effect may be achieved by varying the clearing width.

m. Selective ROW clearing should be used to minimize the number of trees cleared and to minimize contrast between cleared area and woods. It is necessary to define clearing limits and to identify individual trees that could be left standing. Taper rather than cut a clear swath. It is desirable to retain some lower trees and shrubs beneath transmission lines to soften the visual impact (Figure V-18).

n. Tree-to-conductor clearance is preferred over tree-to-center line clearance (Figure V-19). Tree-to-conductor clearance will create a variation in cleared boundary limits (vegetation will be close to poles, far from center of line).

o. Where a ROW enters dense timber from a meadow, or where it crosses major streams, rivers, or roadways in forested areas, a screen of natural vegetation should be retained along the ROW.

p. Trees may be planted to obstruct view of transmission towers (Figure V-20).

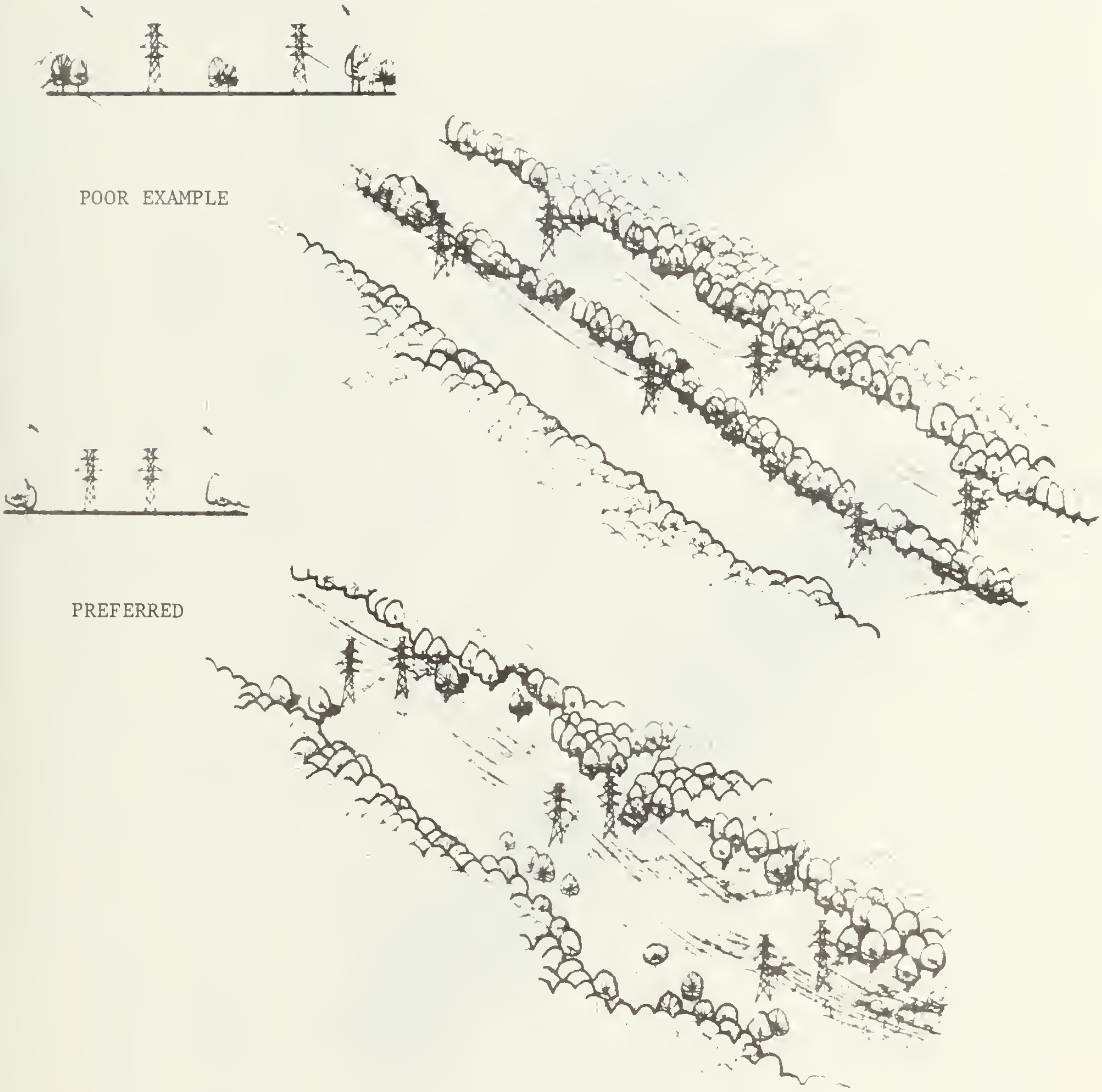
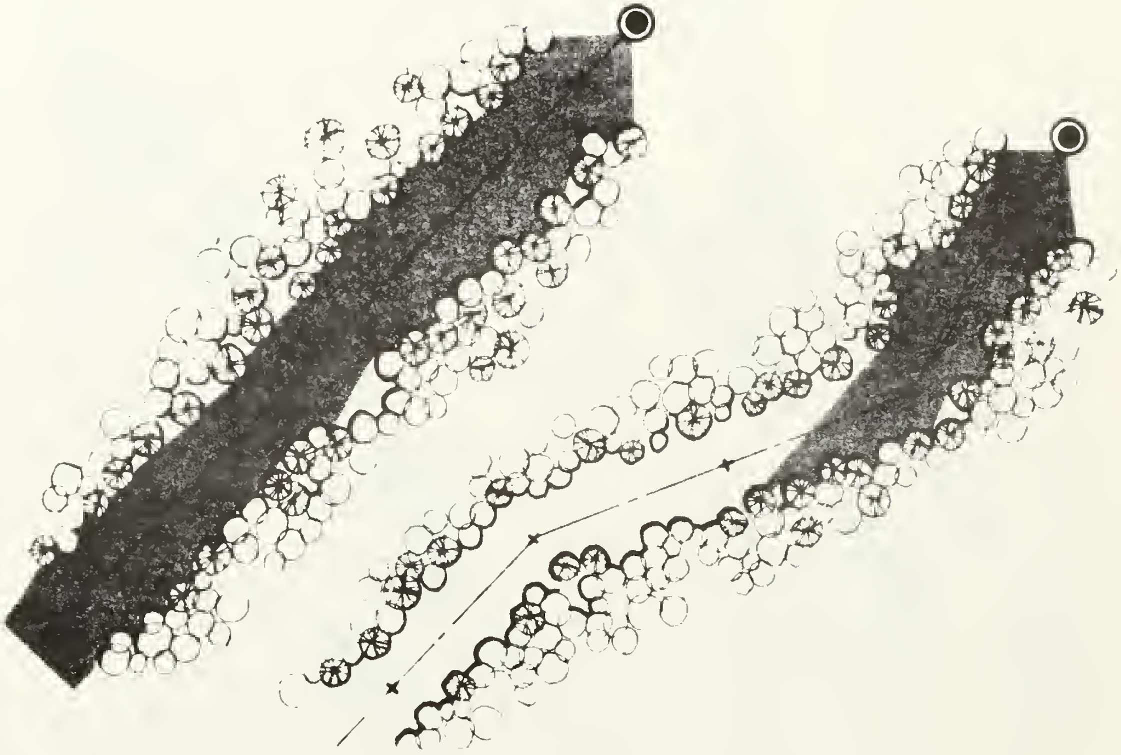


FIGURE V-16

PLACEMENT OF TRANSMISSION TOWERS IN PAIRS
TO REDUCE VISUAL EFFECT



POOR EXAMPLE

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FIGURE V-17

UTILITY LINE ALIGNMENT THROUGH WOODED AREAS

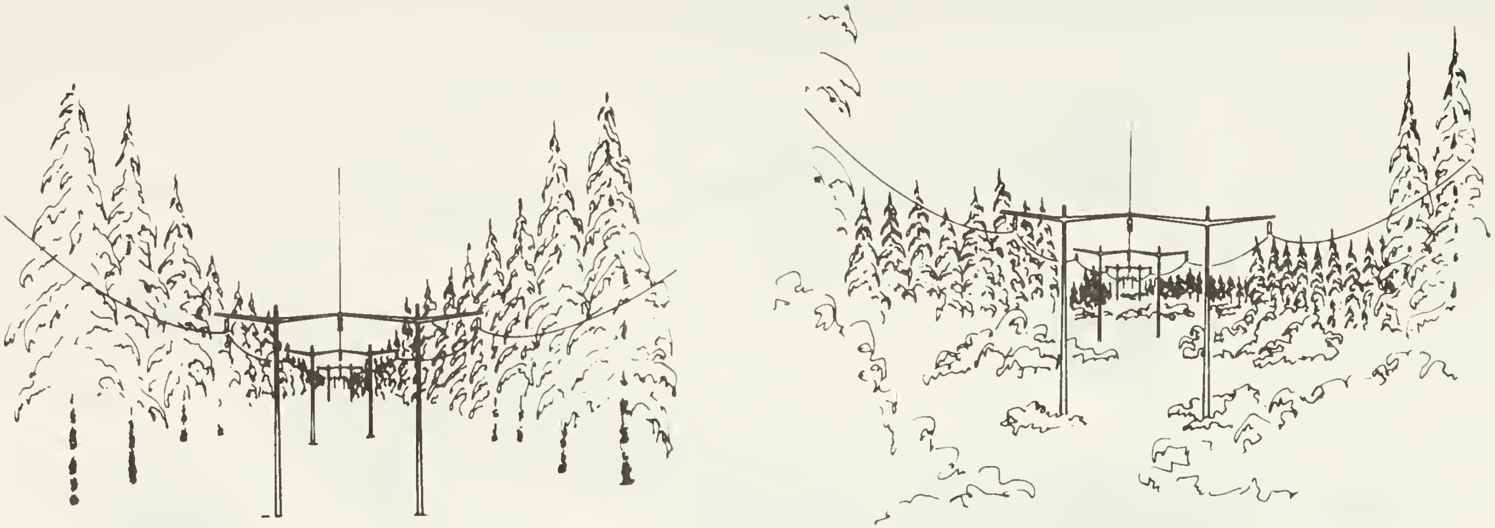

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FIGURE V-18

ROW CLEARING TO REDUCE VISUAL IMPACT
OF TRANSMISSION LINES

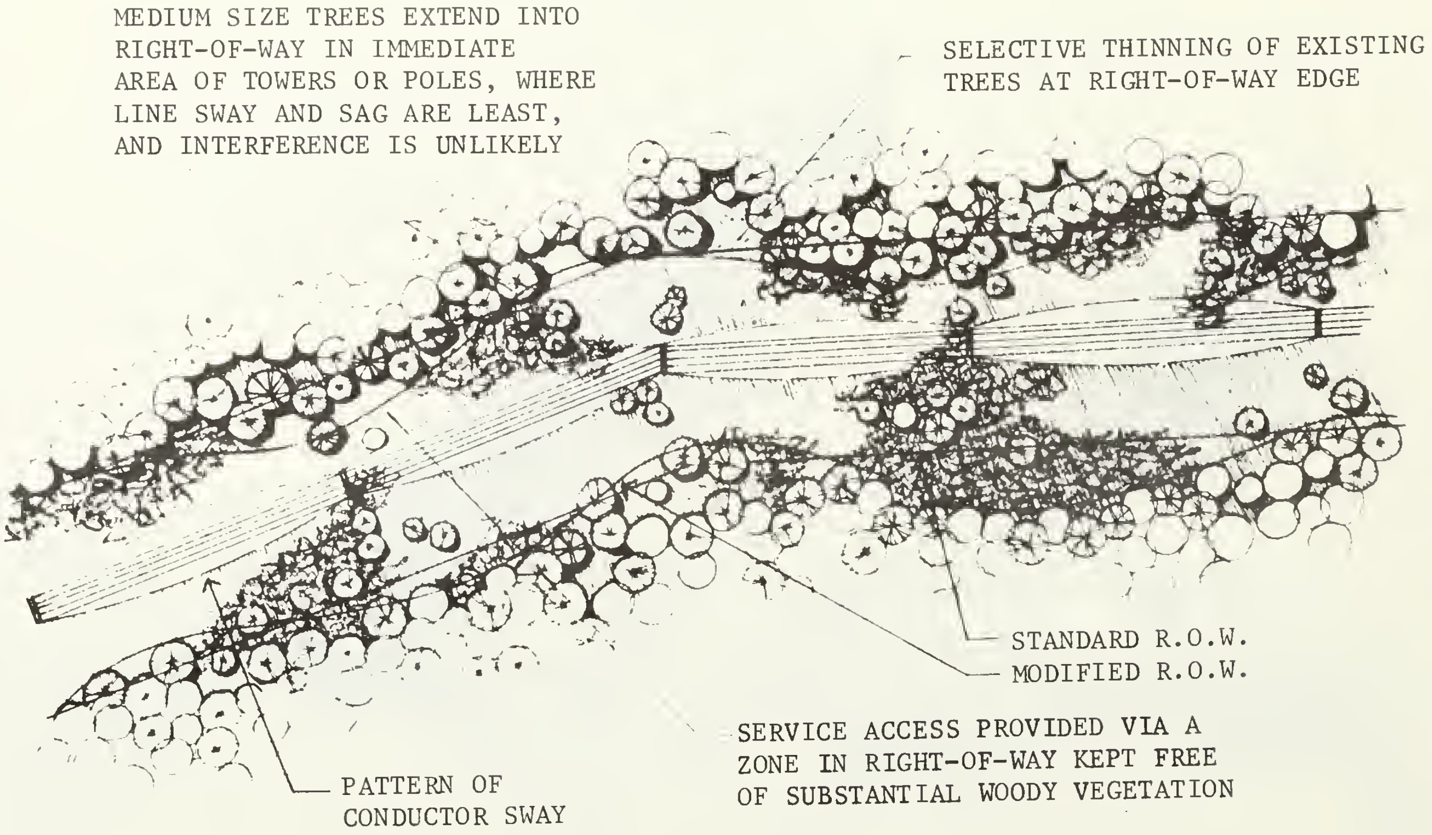
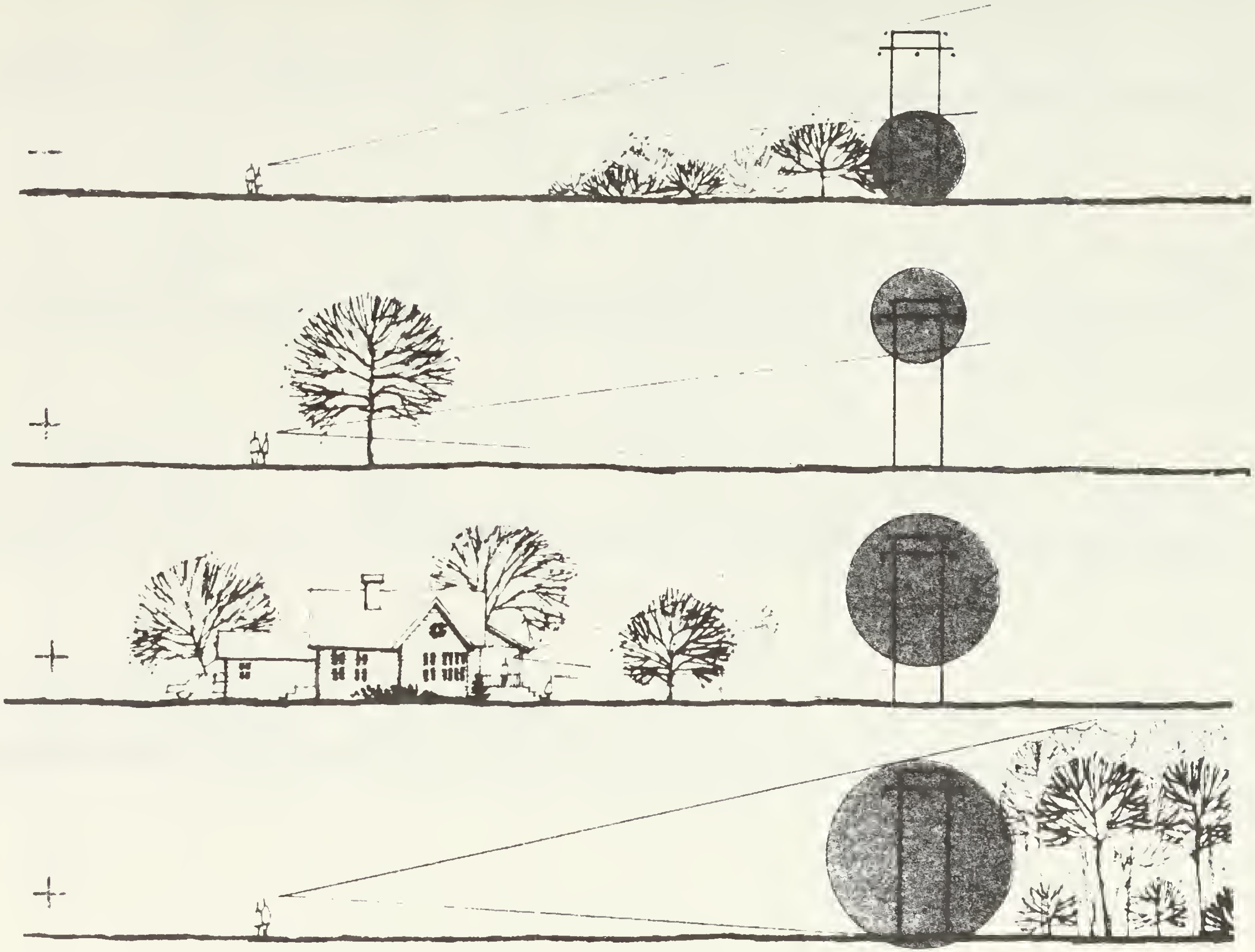

MEDIUM SIZE TREES EXTEND INTO RIGHT-OF-WAY IN IMMEDIATE AREA OF TOWERS OR POLES, WHERE LINE SWAY AND SAG ARE LEAST, AND INTERFERENCE IS UNLIKELY
SELECTIVE THINNING OF EXISTING TREES AT RIGHT-OF-WAY EDGE
STANDARD R.O.W.
MODIFIED R.O.W.
SERVICE ACCESS PROVIDED VIA A ZONE IN RIGHT-OF-WAY KEPT FREE OF SUBSTANTIAL WOODY VEGETATION
PATTERN OF CONDUCTOR SWAY

FIGURE V-19

EFFECTIVE USE OF TREE-TO-CONDUCTOR CLEARANCE
IN TRANSMISSION LINE ROW



- POOR EXAMPLE

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FIGURE V-20

TREE PLANTING TO SCREEN TRANSMISSION LINE TOWERS

Low materials are effective screens only for short-range views.

For maximum screening effectiveness, views from behind or under tall materials are necessary to block viewing of the top of the structure (the top generally being the most bulky and visually obstructive part of the transmission tower).

q. Plant groupings of various sizes, irregularly spaced along a transmission ROW, are effective in interrupting the regular rhythm of structure location (Figure V-21). Dense or continuous plantings cause both the structures and wires to become "lost" against the background branching. However, planting only at each structure will call attention to their rhythmic spacing.

Design of Structures

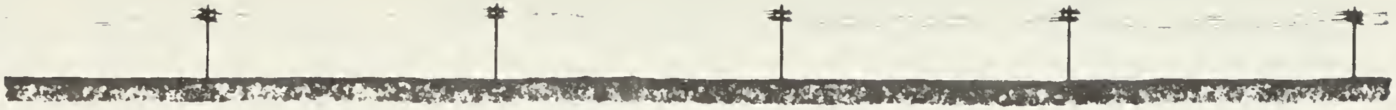
Simplicity. Simplicity, based on overall outline, symmetry, and parallel or orderly arrangement of structural elements, such as conductors and insulators, will minimize attention drawn to the structure. In addition, it is desirable to minimize such elements at the top of the pole. Transmission towers forming an arch (either rounded or with squared corners at the top) have been designed as "esthetic" structures for use in areas regarded as visually sensitive. Tall, slender poles are similarly used. Figure V-22 includes examples of various types of towers which have been designed with the objective of being esthetically pleasing.

Color. Color of transmission towers should be chosen to make the structure as unobtrusive as possible. Choice of color is most effective when it reflects those colors adjacent to the structure.

Warm tones are generally most compatible with both natural and man-made settings. Although many towers may be viewed against the sky, this is too changeable a backdrop to be used as a reliable basis for color choice. When viewed from a shaded side, a tower will generally be seen as a dark form of undistinguishable color. It is generally desirable to limit the number of colors used on a given transmission line to create a sense of visual continuity. Instances where special color may be more desirable include the use of deep-green structures in an evergreen forest and sand colors on the beach towers. In locations that are particularly sensitive to visual intrusions or glare, the use of non-specular wire, which has a dull, gray non-reflective surface, may be advisable.

Material. Wood structures are best in wooded, rural, or residential areas, whereas steel structures are suitable for most modern industrial or commercial areas.

Exotic Color or Design. Exotic color or design should be avoided as either may tend to attract more attention to a tower. The best designed tower is the one that is least noticeable.



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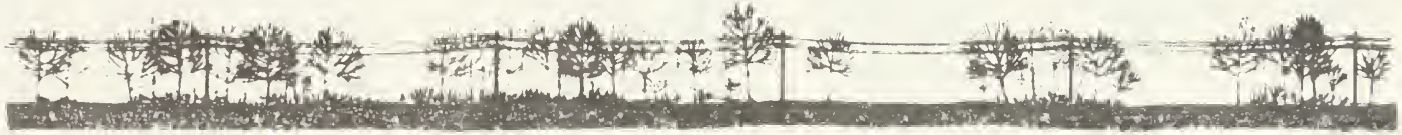

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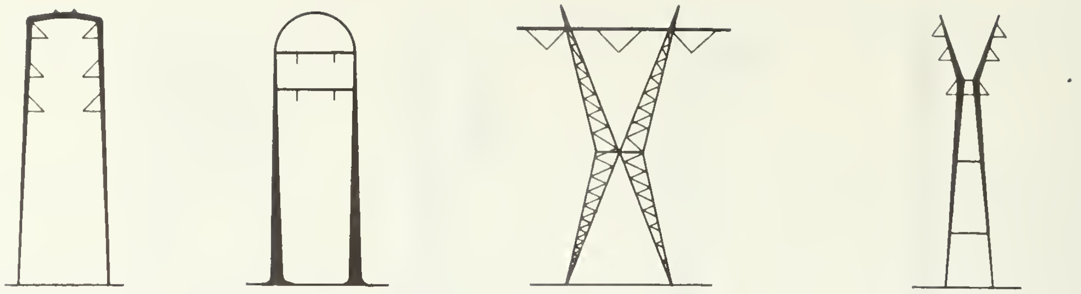
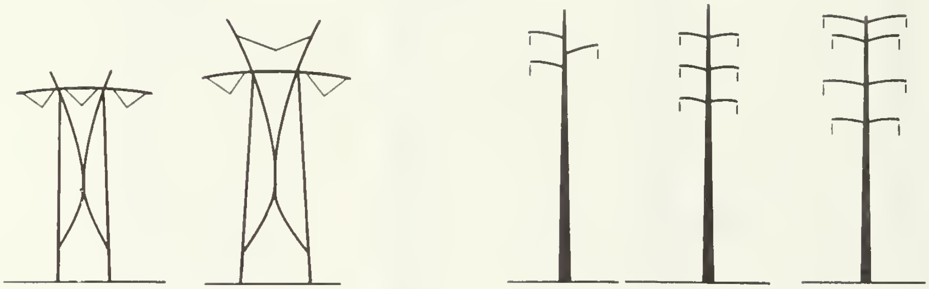
FIGURE V-21

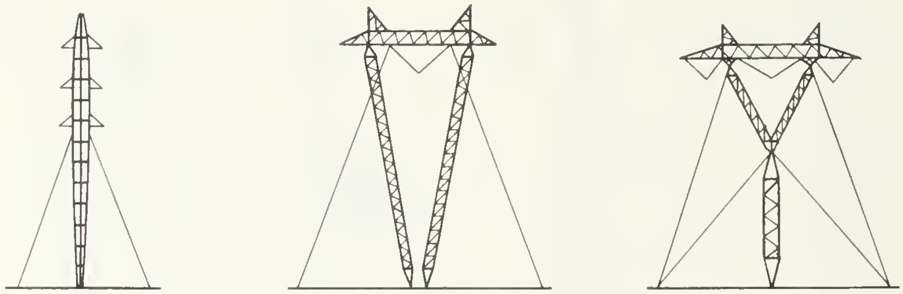
SPACING OF PLANTINGS ALONG TRANSMISSION LINE
RIGHT-OF-WAY



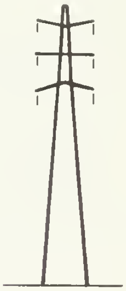
PORTAL STRUCTURES ARCH PORTAL STRUCTURE LATTICE TETRA STRUCTURE TUBULAR TETRA STRUCTURE



CONTEMPORARY K-FRAME CONTEMPORARY SINGLE-POLE STRUCTURES



GUYED SINGLE-MAST STRUCTURE GUYED V-LATTICE STRUCTURE GUYED Y-LATTICE STRUCTURE



CONTEMPORARY TUBULAR STRUCTURE

FIGURE V-22

CONTEMPORARY TOWER DESIGNS

NOISE

The term "noise" as used in this section refers to both objectionable sound -- audible noise in the usual sense -- and electromagnetic interference with communications signals, particularly TV and radio broadcasts.

Construction and Operating Noise

The effect of audible noise on those who hear it may range from minor annoyance (e.g., an irritating background hum or a distant interruptive sound) to a debilitating physical impact that, in the extreme situation, may lead to impairment of the sense of hearing.

Audible noise associated with utility lines is produced largely by equipment used during construction or maintenance. It may also result from operation of compressor or pumping stations required by a pipeline. At a much lower noise level, extra-high voltage transmission lines may produce an audible crackling or humming sound as a result of what is termed "the corona effect."

Unlike visual effects, noise level is relatively easy to quantify. The decibel (dB) is a unit employed in acoustics to measure the ratio between two sound levels and, hence, the increase in sound from a particular noise source. The actual level in decibels at a particular point in space and time is determined by measuring devices. From recorded observations, the average decibel level of equipment associated with construction operations has been determined (Table V-4) and can be used to predict the level that will typically result. The impact of particular noise levels maintained and/or repeated over time can also be estimated from past data based on observed reactions and is shown graphically in Figure V-23.

Construction noise could have a significant impact only when carried out close to human habitation. As illustrated in Table V-4 and Figure V-23, the level of noise from most construction equipment would not reach an unacceptable level at a distance of 1000 feet or more. Thus, construction of lines through remote areas cannot be expected to create a noise problem. Through residential zones and commercial districts, or near institutions, where construction activity might be carried out within 500 feet of houses or other buildings, the noise impact of protracted operations could reach an unacceptable level.

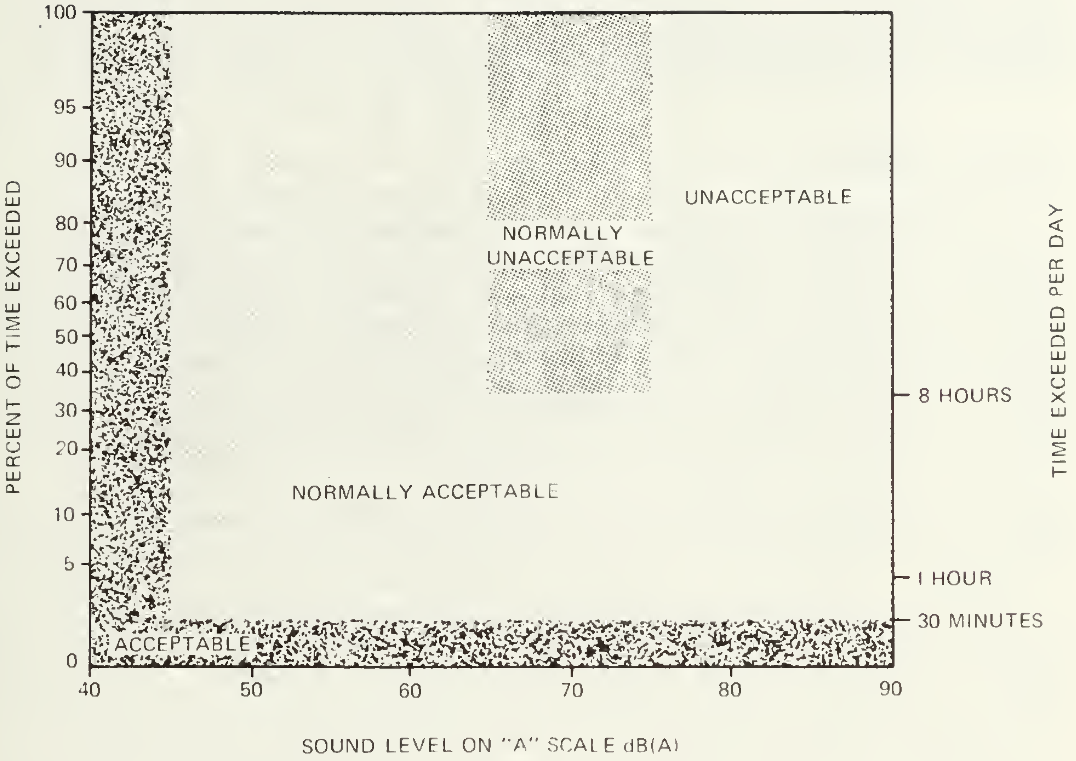
If construction in populated areas is unavoidable, the adverse impact may be mitigated to some degree by locating the noise source behind sound barriers such as land mass and vegetation; locating the line so that construction activity will be at maximum distance from houses, buildings, and other points at which there will be numbers of

TABLE V-4

RESULTANT SOUND LEVELS FROM CONSTRUCTION EQUIPMENT

SOURCE	SOUND LEVEL, dB(A) AT INDICATED DISTANCE FROM SOURCE				
	50 ft.	100 ft.	200 ft.	500 ft.	1000 ft.
Trucks, cranes, bulldozers, etc. (Featuring diesel-type internal combustion engines)	70-95	64-89	58-83	50-75	44-69
Air compressors and other Stationary sources, typically diesel powered	76-86	70-80	64-74	56-66	50-60
Pile driver	105	99	93	85	79
Front end loaders	73-86	67-80	61-74	53-66	47-60

Source: U.S. Environmental Protection Agency, "Report on the Administration of the Envioronmental Potection Agency to the President and Congress on Noise," Senate Document No. 92-93, U.S. Government Printing Office, Washington, D.C., February 1972.



Source: New York State Department of Environmental Conservation, Prevention and Control of Environmental Noise Pollution, August 1973.

FIGURE V-23

NOISE CRITERIA

people; and restricting noisiest construction activities to times when sensitivity may be minimized.

The same is true of pumping and conpressor stations on pipelines. The problem may be avoided by locating these stations remote from homes, offices, and other buildings regularly occupied by people. Construction to reduce noise and installation of mufflers have also been used.

Corona Effects

Corona has already been noted in Section III in connection with concern over possible effects on air quality, which appear to be insignificant. However, three impacts associated with corona discharge which have occasionally caused problems under special conditions are radio interference (RI), television interference (TVI), and audible noise. These effects are not likely to be noticeable at voltages below 345 kV but may require special precautions at higher voltages, especially at 500 kV and above. Any irregularities on the surface of a conductor will increase corona discharge. Therefore, the potential for corona discharge is low on smooth, clean surfaces and will increase as the amount of moisture, dust, aerosol gases, pollution, bugs, and nicks on the conductor increases. RI has been significant only in the AM broadcast band. To ensure good quality AM reception, RI should not exceed 40 dB above 1 microvolt per meter (μV/m) for Type A stations and 30 dB for Type B stations. At 765 kV, levels of interference higher than 40 dB above 1 μV/m are expected within a lateral distance of 200 feet of a line during fair weather; during foul weather, when RI levels are much higher, the critical distance may be 300 to 400 feet from the centerline. RI levels can be reduced by design measures such as increasing the size of bundle conductors and making a proper selection of subconductor spacing and line clearances. For example, a reduction of about 9 dB above 1 μV/m is achieved by increasing subconductor diameter of 3-conductor bundles from 1.427 inches to 1.82 inches (Aerospace, 1975; Shah, 1974).

TVI has occasionally been reported as a significant problem in rural and fringe reception areas. TVI is strongly affected by weather; during heavy snow conditions a level four times normal may be reached. The allowable level for TVI (as specified by the FCC) for rural and fringe areas is reached at a lateral distance of 500 feet or greater from a 500 kV line. Elsewhere, a distance of 100 feet should suffice. As with RI, standard construction practices are available to reduce TVI (Aerospace, 1975; Shah, 1974).

When electrons are drifted away from the surface of the conductor, a crackling noise is produced that may reach audible levels. This phenomenon primarily occurs during wet weather, when water droplets formed under the conductor are electrically stressed before leaving the conductor surface.

Conductor surface condition, precipitation on the conductor, and wind velocity all affect audible noise emission. The effects can represent a nuisance in the vicinity of a 500 kV power line. Below a sound pressure level of 52.5 dB(A), few complaints result, whereas a critical level associated with numerous complaints occurs at 58.5 dB(A) (Aerospace, 1975). The audible noise profile for heavy-rain conditions of a typical 500 kV line shows a level above 58 dB(A) at a lateral distance of about 200 feet from the centerline, with diminution to 52.5 dB(A) at a lateral distance of about 300 feet (Shah, 1974).

Audible noise levels are significantly less for 3-conductor than for 2-conductor bundles and drop sharply (both for fair and foul weather conditions) as sub-conductor diameter is increased. For example, the audible noise at 525 kV under the outermost conductor in a 3-conductor bundle drops linearly from about 60 dB(A) to 44 dB(A) in after-rain conditions as the sub-conductor diameter increases from 1.1 to slightly over 1.4 inches, after which it levels off. For heavy-rain conditions, the drop is less linear, from about 62 dB(A) at a diameter of 1.1 inches to 54 dB(A) at 1.9 inches. Similar drops as a function of sub-conductor diameter are observable with a 2-conductor bundle (Shah, 1974).

Other methods to minimize the impact and amount of corona include lowering the voltage level, increasing the phase spacing, and increasing the heights of the phase conductors aboveground. In areas of high humidity or fog, an increase in a load current through the line may minimize corona activity by keeping moisture from condensing on the cold conductor. It is advisable to wash insulators periodically, especially in locations where dusty or salt spray conditions are common. However, due to unexpected atmospheric changes, it is not always possible to eliminate all corona discharge. Therefore, wider strips of land may be provided for transmission line ROWs through existing or proposed residential areas to prevent homes from being built close to transmission lines. In general, greater spacings away from lines are required at higher operating voltages. However, there are designs available for voltages up to 1200 kV which can be expected to produce no more radio and TV interference or audible noise than do standard 500 kV lines.

PRESSURE ON COMMUNITY SERVICES

It is not likely that construction and operation of a utility line or corridor will bring heavy pressures on any local community's capability to provide housing, medical, and other facilities required or to render educational, protective, and other necessary services. The rate at which construction proceeds and the fact that it is normally spread over a considerable linear distance (in contrast with a large electric generating plant, for example) seldom results in a concentration of work force at any one point for a long enough period of time to strain a community's resources or its infrastructure. However, it should be determined whether any heavy influx of population will result for any locality. If so, assurance may be necessary of means to mitigate any possible adverse effects, For example, if large numbers of families with school children should be brought into a remote region for a school year, outside support may be necessary to supplement local physical facilities and teaching staffs. Mobile hospital facilities or temporary assignment of doctors could conceivably be required if there should be indication of exceptional concentrations of a work force over an extended period of time.

The Colstrip Generation Project (Montana Department of Natural Resources and Conservation, 1974) is one of the few for which attempts were made to calculate the demands on community service from construction of a utility (transmission) line. Statistics from the Westinghouse Environmental Systems report (1973) indicate that 300 workers and 6 months would be needed to complete the 110-mile transmission line. The Colstrip study then estimated that, assuming all 300 construction personnel immigrate into the area and 50 percent of the workers would be accompanied by 2.5 dependents each, a total population increase of only 675 persons would occur. Impact on services in any one community would generally be small, as it is unlikely that any sizable portion of the 675 persons would settle in the same community.

For most utility lines, the estimate of potential impact on community services can be expected to be similar to that predicted for the Colstrip transmission line. A complete environmental assessment would require that this point be established.

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SECTION VI
TECHNICAL FACTORS

SECTION VI

TECHNICAL FACTORS

OVERVIEW

Purpose and Scope

This section presents the principal technical factors that should be considered in deciding where to locate a utility line, and that should be addressed in any proposal for a specific installation. The technical factors include all of the system parameters by which the utility line is measured as to performance in meeting its intended purpose. How far environmental considerations can influence location of the line is constrained by the technical options available. This section provides some basic references as to the nature of the technical factors, including some quantitative guidance as to what the design requirements and options are likely to be.

Many of the individual factors treated relate to more than one consideration discussed in this section. For example, clearance requirements influence ROW dimensions and construction practices, while at the same time they are based on considerations of safety and reliability. Voltage requirements and number of circuits are important system characteristics of a power transmission line that also happen to affect ROW dimensions (particularly in terms of the width and clearance required). Such interrelationships as these have made it necessary to somewhat arbitrarily group factors into particular subsections. The relationships between the principal factors considered in this section and the major subsection headings are as follows:

- RIGHT-OF-WAY DETERMINANTS
    - End points of the line
    - Power line losses as a function of loading and distance
    - Distances to major users such as load centers, and injection and delivery points
    - Location of major facilities that must be incorporated or with which the line must connect (e.g., switching centers, substations)
    - Identification and location of supply points for moving men and material for construction
    - Additional road construction required to provide access to the line
- SYSTEM CHARACTERISTICS
    - For electric transmission lines:

        Voltage
        Mode or type of current
        Number of conductors
        Number of circuits

- For pipelines:
    - System capacity
    - Flow rate
    - Pipe size
    - Operating pressure
    - Booster or compressor stations
- Reliability standards
- Causes of transmission line outages and pipeline failures
- Protective measures
- General safety standards
- Protection against special hazards such as grounding to minimize danger from induced voltage in the vicinity of power lines and cathodic protection for pipelines

- RIGHT-OF-WAY DIMENSIONS
    - Length of line segments
    - ROW widths
    - Relative cost per mile of line
    - Required clearances
    - Length of power line spans
    - Power line sag and conductor swing
    - Types of power line structure (poles and towers)
    - Requirements of underground electric transmission
    - Pipeline widths and depths
    - Pipeline material

- SPECIAL REQUIREMENTS
    - Pipeline control stations
    - Tank farms
    - Heat dissipation in underground power lines
    - Transition points between underground and above-surface installation
    - Scouring problem in bridge-type water crossings
    - Problems and tradeoffs in expanding an existing ROW

- CONSTRUCTION AND MAINTENANCE PRACTICES
    - Excavation techniques
    - Restoration requirements
    - Constraints on pipeline excavation
    - Crossings
        - Submarine
        - Overhead water crossings
        - Crossing other utility ROWS
    - Vegetation control

- Easements
- Construction times
- Requirements for future growth

Major Interrelationships

In a sense, all of the objectives presented earlier for consideration in selecting the location of a utility corridor are interrelated with technical factors because meeting any objective can have some influence on system design. For example, the length of a given segment of the corridor may be increased by a decision to avoid an alternative path with some undesirable environmental effects. Major interrelationships exist between the technical factors or system variables and the systems objectives of economy, stability/reliability, esthetic compatibility; and land use compatibility. Additionally, specific features of the ROW and construction and maintenance practices can significantly affect the natural environment.

Constraints

The basic location of a utility line or a ROW is defined in terms of the points it must serve. These points, which must be connected by a pathway, pose the initial constraint on the degree of freedom available in designing the route. The process of further determining the line consists of making selections from alternative ways of linking the points to be connected.

From the standpoint of technical factors, the principal constraints (which in specific situations may result in eliminating an area from further consideration in locating a utility line or corridor) are those relating to the need to ensure solid foundation conditions by avoiding unstable terrain and ROW dimensional requirements imposed by safety and interference factors. The need for physical stability of a line and maintenance capability tend to preclude areas where subsidence, excessive erosion, flooding or other hazards discussed in Section III under natural and physical factors make line placement untenable. The dimensions of a ROW, particularly adequate width, are related both to providing adequate reliability of the line (minimization of outtage due to some failure) and ensuring safety of the public against serious consequences from accidents, from noise, and from interference with communications. These factors can lead to precluding location of a given line segment in a specific area. For example, a potential segment of a route from Point A to Point B may be avoided in favor of an alternative from Point A to Point C if the ROW width available from A to B is too severely constrained either by adverse terrain features or by man-made conditions, as happened near the eastern end of the Oahu Energy Corridor (State of Hawaii, 1971). Details of the dimensional requirements are presented in a later subsection in Section VI.

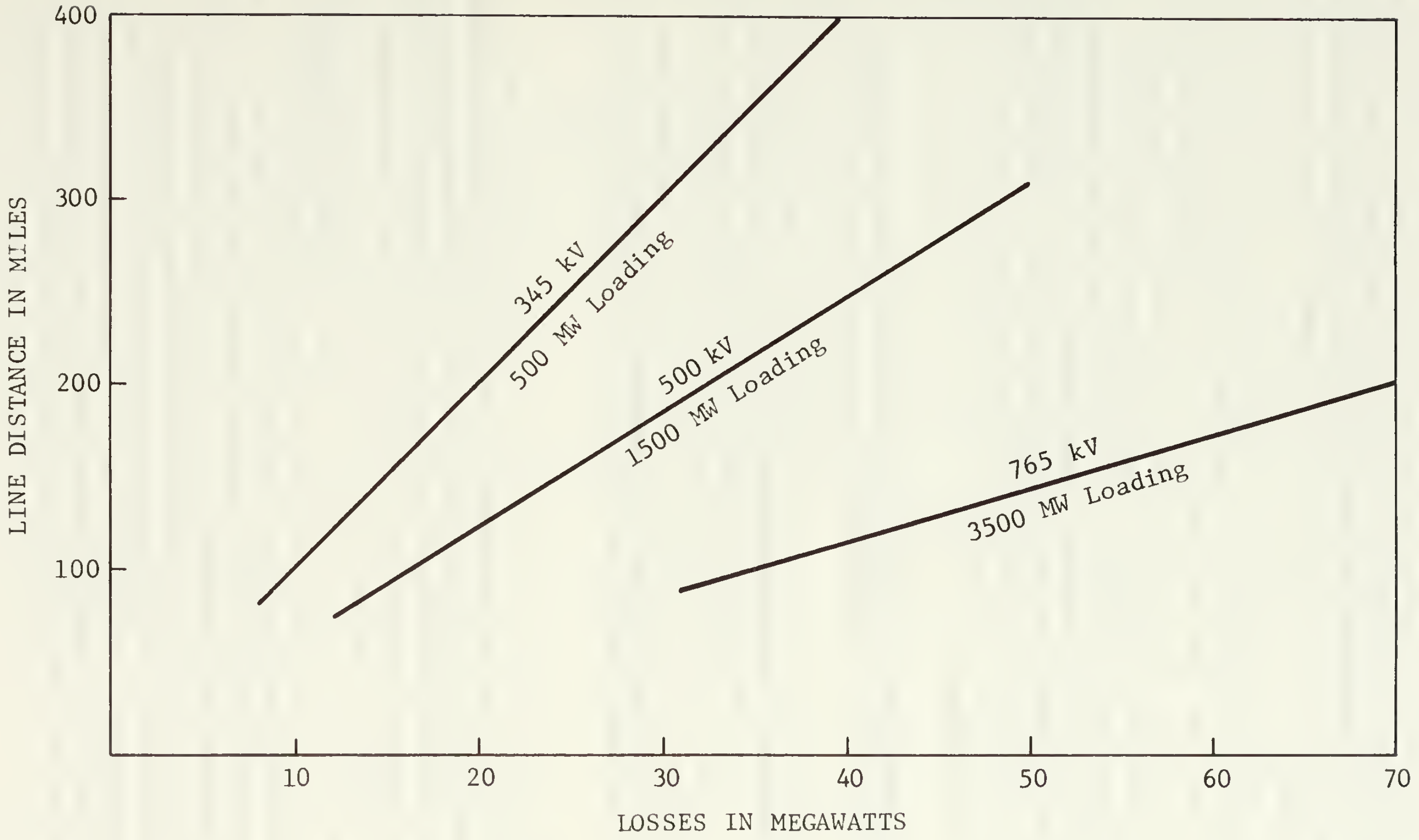
The degree of separation required between any two adjacent utility lines affects feasibility of expanding or sharing an existing ROW. In this capacity, ROW dimensions may function as binding constraints in terms of not interfering with another utility's operations. It may happen that an existing corridor is not wide enough to permit construction of another line either of the same or of a different utility. Available land may be inadequate to permit routing a line between points A and B because there would be insufficient separation between the line and one already located on an adjacent stretch. (More specific information on separation requirements appears in the subsection on ROW dimensions below.) Typically, overhead utility lines (such as electric transmission facilities) avoid a location that constitutes a potential hazard to or from aircraft landing or takeoff patterns, and corridors generally exclude locations where construction activities would interfere with heavy highway traffic, congested intersections, and the like.

Sensitive ecological areas constitute an additional type of critical constraint on technical factors in terms of precluding particular design options. For example, to avoid adverse environmental effects from construction activities while laying a pipeline through a marsh or stretch of wetland, the pipeline might cross the area as an above-surface structure. Sometimes the constraint might operate in regard to maintenance practices, as when helicopters must be used to maintain a transmission line because of the damage to a thin crust of topsoil or to vegetation from a series of access roads leading to the tower structures.

Key Points

Technical factors provide enough flexibility to enable virtually all environmental objectives to be met in the design and location of a utility line. However, the cost is sometimes high and, indeed, may be prohibitive. In adjusting the location of a corridor or ROW because of environmental considerations, the most obvious effect will be an increased cost in constructing and/or maintaining the line, with attendant higher prices that must be paid by the utility's various consumers.

Sometimes, the cost may have an indirect effect, in terms of reduced system performance. For example, in an electric transmission line, power losses are a function of distance (see Figure VI-1). Thus, if the length of the line must be increased, a greater amount of power will be lost (principally from resistance in the line). In order to deliver a specified amount of power for consumption, the amount generated must be increased; and the percentage of increase necessary is as great as, or slightly greater than, the percentage of line loss. In addition to increased dollar costs for generating additional power, there will be indirect environmental effects resulting from such requirements as mining and consuming additional amounts of fuel and resources used in



Source: Derived from 1970 National Power Survey, Federal Power Commission, 1971, Vol. I, Figure 13.7.

FIGURE **VI-1**

RESISTANCE LINE LOSSES (IN MW) AS A FUNCTION OF DISTANCE, LOADING, VOLTAGE constructing the line. In many instances, the practical environmental impacts of increased length may be negligible; they should not, however, be overlooked in a comprehensive evaluation of alternative line locations, because the potential for impact increases with an increase in length of the line.

Similarly, an increase in the length of an oil, coal slurry or gas pipeline resulting from environmental considerations may be sufficient to increase the required number of booster or compressor stations and, hence, the amount of auxiliary power required to move the fluid to the point of delivery. This action reduces, although perhaps by only a negligible amount, the net amount of energy (in the form of heat or of power derived from using the oil or gas as fuel) available from the delivered product of the pipeline.

RIGHT-OF-WAY DETERMINANTS

Initial constraints on location of a utility line are provided by the end points and by the following factors:

- Any intermediate users of the line, such as load centers that must be served by a transmission line, and injection and delivery points resulting in input to and output from a pipeline; and
- The existence of any facilities, such as switching stations, by which a transmission line may be tied into a larger network, or tapoffs to branch or feeder lines.

User Locations

The end points of a utility line may be taken as fixed and defining the boundary for the location and impact study. Other things being equal, the most economic routing of a line is the straight line distance between the end points. This straight-line route (which for longer corridors may actually be measured on a great circle as for the Northern Border Pipeline) is, for various reasons, hardly ever used. However, measured in miles, it does give the minimum possible length of the route as reference point against which to compare all alternative paths. Any deviations from this straight-line route should be justified on environmental and/or engineering (including cost-effectiveness) grounds. It is desirable to approach this minimum length as closely as possible within the existing constraints in order to minimize costs in dollars and in line performance. In addition to variable construction costs which (other things being equal)* are a linear function of distance, increased length of a transmission line may lead to greater operating costs.

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*In practice, they seldom are equal because there will be differences reflecting such factors as access, clearing requirements, slope, foundation conditions, etc.

Lengthening a pipeline by some increment (which will depend upon topography as well as upon properties of the fluid transported and transmission parameters of the line) results in an additional pressure drop in the line and can lead to a discontinuous jump in cost if an additional booster or compressor station should be required. Considerations affecting the number of such stations are presented under transmission parameters. In the present context, the important point to note is that for a given pipe diameter, there may be critical or threshold lengths of pipelines; if exceeded, it will result in raising the cost disproportionately.

Both intermediate users of the line and essential connecting facilities constitute primary engineering constraints on line routing. There is seldom, if ever, any freedom of choice as to providing for line connections with these points, the need for which has normally been established by a previous study not part of the process of selecting a route or evaluating the utility line impact. But there may be options as to how close the line should come to each point.

The most economical route will involve tradeoffs, including distances and requirements of the intermediate points, based typically on the following considerations:

- Distance of each load center, essential connection, or other user from the two end points of the line.
- Distance in miles between every pair of adjacent intermediate points.
- For pipelines, frequency of injection or delivery, and rates, in terms of standard cubic feet (SCF), gallons or barrels per day.

Most transmission lines require one or more substations. The question of appropriate size often arises. Table VI-1 gives typical area requirements for electrical substations. Since substations provide for a change from one voltage to another, the total dimensions are determined by the requirements for the two voltages involved.

Access Requirements

The term "access requirements" as used here denotes the capability to move men and equipment from potential supply centers for construction and maintenance. It is not to be confused with the engineering difficulties of working in unfavorable terrain nor with the impact of maintenance practices requiring access to the line. These problems are considered elsewhere. It refers rather to the logistics of movement to sites on the utility line, in terms of distances involved and the transportation network available (secondary roads leading off main highways and surfaced or graded roads that might be used to give direct access to the corridor).

TABLE VI-1

TYPICAL SPACE REQUIREMENTS OF ELECTRICAL SUBSTATIONS

	SUBSTATIONS*		SERVICE AREA
LINE VOLTAGE (kV)	(a) AREA DIMENSIONS PER LINE BAY (feet)	(b) AREA DIMENSIONS FOR ACCESS (feet)	(c) AREA FOR SERVICE BLDG. (sq. ft.)
115	60 x 150	80 x 300	10,000
230	90 x 220	90 x 440	20,000
345	112 x 360	100 x 720	30,000
500	200 x 500	150 x 1000	40,000

Notes: Total Area = (Number of lines or transformer circuits) times (a) plus (b) plus (c) plus (contingencies). Contingencies include transformer areas, area for oil storage tanks, parking area, area required for grading outside fence, etc.

* Low profile substations. Areas for center takeoff type substations would be less by 10 to 25 percent.

Source: Bureau of Reclamation, U. S. Department of the Interior, informal notes, 1974.

Few routing studies or impact statements dealing with utility corridors indicate that these considerations impose significant constraints on line location. Nevertheless, they involve valid engineering and environmental concepts. The need to operate at a longer distance from a supply center or staging area where men and materials are available or can readily be assembled results, other things being equal, in somewhat greater monetary cost and delays. Secondary effects of pollution from exhausts of transportation vehicles increase proportionately with the time required to operate them. The need to construct routes for passage from the existing road system directly to the corridor represents both a further engineering problem and a form of potential environmental degradation in terms of land requirements, ecologic impact, pollutant emissions, and resource consumption. Often the differences between these factors as they affect alternative paths may be negligible. However, an impact assessment should establish whether there are significant differences and if so take them into account.

When appropriate, the factors involved may be specified and measured as follows for each alternative line segment:

- Identification and location of supply point from which men and material would be moved.
- Maximum, minimum, and average distance to the line segment.
- Mode of transportation (i.e., surface or helicopter).
- Average transportation time to the line segment.
- Miles of additional road construction required to provide access to the line segment at appropriate points.

SYSTEM CHARACTERISTICS

System characteristics consist of the transmission parameters (what will be sent and how), together with the considerations of reliability and safety.

Transmission Parameters

The transmission parameters include the variables that define the nature of the line in terms of how it accomplishes its mission in moving energy or material. The values of the parameters are set by the utility, based on engineering considerations, and do not normally present alternatives for selection in line routing or control of environmental impact. They are considered here from the standpoint of the values that may be encountered and their influence on the features that determine environmental impact.

Electric Transmission Lines

- Voltage
- Mode or type of current (a.c. or d.c.)

- Number of conductors
- Number of circuits

The voltage, (electromotive force that, when applied to a conductor, moves current), is selected for a transmission line by the economics of system design. Principal determining factors are the power needs, equipment costs and construction practices. Commonly encountered voltages (in kilovolts) are 115, 230, 345, 500 and, more recently, 765. The trend is to higher voltages which enable a transmission line to carry an increased amount of energy (Figure VI-2). Also, for a given megawattage of power, line losses are less; however, somewhat larger structures are needed to carry the higher voltages (as discussed below), thus affecting clearance and ROW width requirements. Since the increases in size are not proportional to the increase in energy carried, for a given total amount of power transmitted it becomes more efficient (in terms both of electric power loss and of minimum land use) to use a higher voltage.

The type of current transmitted is usually alternating, in which the direction reverses periodically. In the United States, 60-cycle alternating current (a.c.), in which the reversal in each direction occurs 60 times per second, (making a total of 120 per second), is almost universally employed. Direct current (d.c.) is relatively little used in the United States, an exception being a major transmission line linking Los Angeles with northern Oregon. In 1970, 400-kV d.c. lines comprised less than 1.5% of total transmission-line mileage in the nation. For direct current, the cost of the transmission line itself is only about 2/3 that of an equivalent a.c. line, but expensive conversion equipment is required at both the generating and the distributing ends of the line. The economics of using d.c. varies with distance and transmission is often cost effective on long lines between fixed terminals. Alternating current has important advantages. It can be easily tapped into intermediate networks, switched with circuit breakers, and readily integrated into a network.

In alternating current, where the voltage varies continuously with time so that when plotted it appears as a mathematical sine wave, it is possible to generate distinct voltages out of time phase with one another by a constant amount. It is the usual practice to generate power for transmission in three distinct and equally spaced phases, separately transmitted by parallel conductors on the same line. One-phase and two-phase voltage could also be generated and transmitted but are less efficient than a three-phase system and are not normally encountered.

Table VI-2 contrasts some of the most significant characteristics of a.c. and d.c. lines. The height of structures will be the same, because ground clearances required for a.c. and d.c. tend to be similar.

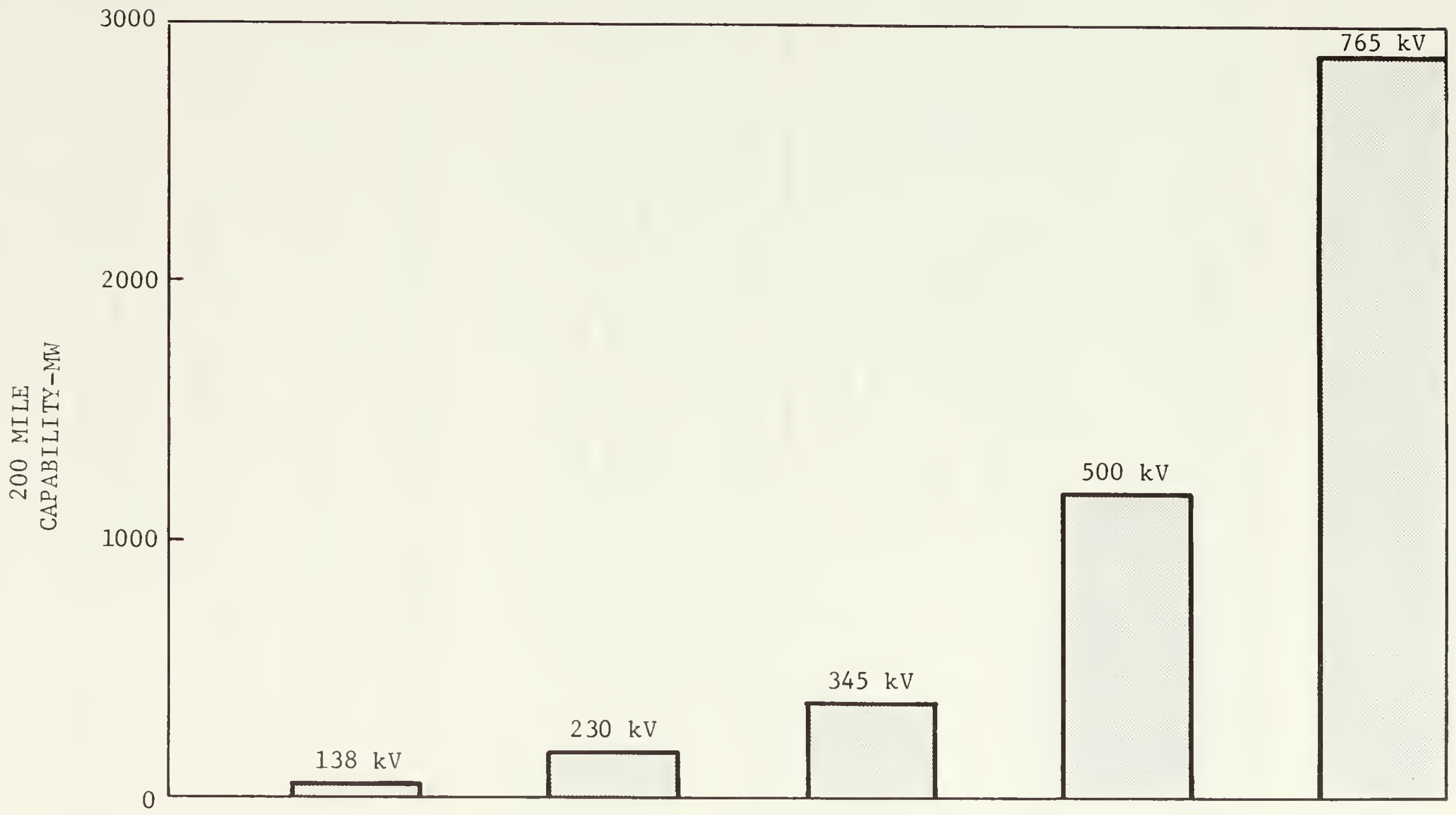

FIGURE VI-2

RELATIVE TRANSMISSION CAPABILITIES

TABLE VI-2

CHARACTERISTICS OF AC AND DC LINES

CHARACTERISTICS	AC(3-PHASE)	DC
Number of conductors per circuit	3	2*
Relative power capacity	1	1.3 - 1.5
Relative advantage(s)	Avoids expensive equipment and expense of land needed for conversion	Lower line unit costs; narrower ROW; greater power capatiy.

The number of circuits on a transmission line refers to the number of independent power lines that can be supported together. Lines are ordinarily either single- or double-circuit. On a double circuit line each circuit must be comprised of separate conductors with a sufficient distance between to ensure proper insulation and minimize the danger of faulting. An equivalent amount of power can be carried on a double-circuit line with less width requirement than on two separate single-circuit lines. There is some lowering of system reliability due to using one set of structures for both circuits.

Pipelines

The principal transmission parameters of pipelines that affect choice of routing and environmental impact include:

- System capacity
- Number of separate pipes
- Flow rate
- Pipe size
- Operating pressue
- Type, size, and spacing of booster or compressor stations

System capacity refers to the maximum volume of material--whether gas, some form of oil, or a slurry--which can be delivered by the pipeline as throughput over some appreciable time, such as a day. For liquid petroleum and its products, capacity is typically measured in barrels per day (bbl/day). It could also be measured in gallons per day (gal/day). The usual measure of gas capacity is thousands of cubic feet per day (MCF/day) or millions of cubic feet per day (MMCF/day).* System capacity is a very basic parameter, as it represents the goal of the system.

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*On the West Intertie. Many foreign EHV-DC lines use three conductors.

The flow rate refers to the number of units of fluid that can move in a pipeline while it is in operation, as measured within a smaller interval of time (such as an hour or a minute) than is used in expressing system capacity. Capacity is obviously a multiple of the flow rate of a single pipeline. When flow rate is divided by the velocity in which the pipeline contents move in miles per hour or feet per minute, the result expresses the pipeline content in volume per mile (or feet as the case may be). Flow rate is an indicator of the maximum spillage that could be expected from a major accident that ruptured the pipeline so severely that the contents escaped freely.

Normally, the term "pipeline" refers to a single continuous pipe which carries all of the fluid moving between the two end points. When it is necessary to expand capacity within an existing corridor, the addition is thought of as another pipeline. But there is nothing to prevent actually laying more than one pipeline at the same time so as to provide greater capacity from the start than a single length of pipe will furnish. In such a situation, the total capacity would be the sum of the maximum throughput in each individual line.

The number of individual pipes will affect the ROW width, since additional space would be needed to place any other pipe(s) parallel to the first. Distributing a given capacity between two or more pipes would also affect the remaining parameters, which would then have to be determined for a divided load. It is very unlikely to encounter an initially built double pipeline. More frequently, an existing line is expanded by adding a second.

The size of pipe used is paramount in determining ROW width. The rate at which a particular fluid will move through a pipe of specified size depends not only on the operating system pressure chosen, but also on properties of the fluid itself. For pipelines moving liquid products the relationship is given in the Appendix to Section VI. For a specific liquid with well-defined weight, viscosity (degree of resistance to flow), and constant pressure, the rate at which rate of flow increases with increasing pipe diameter is illustrated for a specific petroleum product in Figure VI-3. Pipe size is measured in terms of diameter and wall thickness. As would be expected, wall thickness tends to increase as diameter becomes larger. Table VI-3 shows typical dimensions for oil pipelines as well as flow rates for a commonly encountered grade of oil in pipelines of representative sizes, assuming a pressure loss of

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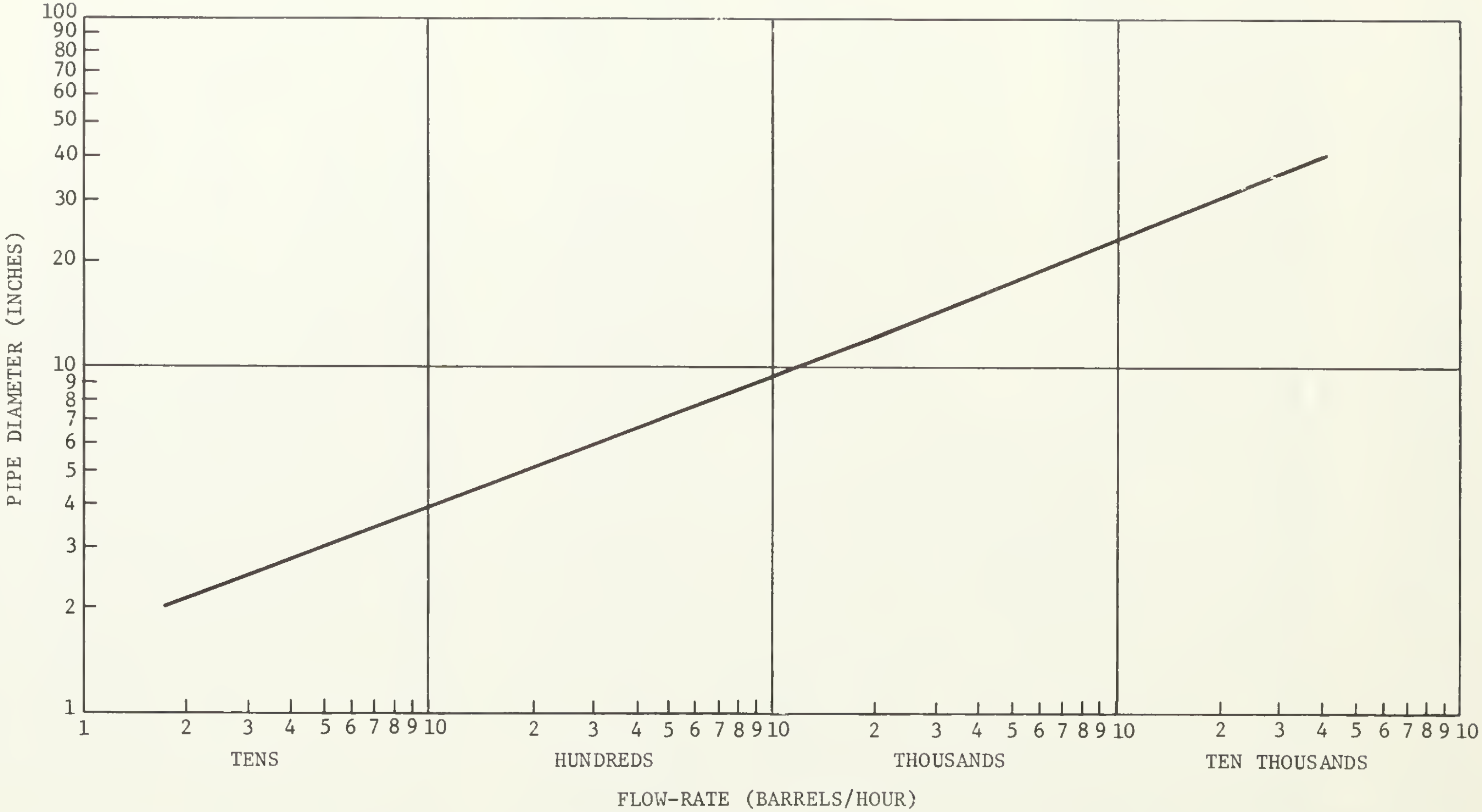
*In the conventional abbreviations, the "M" is derived from the Latin word for thousand. "Million" is represented as a "thousand thousands."



Source: Petroleum Extension Service, Oil Pipeline Construction and Maintenance, 2nd ed., Vol. II, Division of Extension, The University of Texas, Austin, Texas, April 1973.

FIGURE VI-3

Flow rate is for weight 38° oil.

FLOW RATE VERSUS PIPE SIZE FOR A REPRESENTATIVE GRADE OF OIL

TABLE VI-3

PIPELINE DIMENSIONS AND NOMINAL FLOW CHARACTERISTICS

DIAMETER IN INCHES			WEIGHT	VOLUME*	FLOW	VELOCITY*	
Nominal	Outside	Inside	Lbs/Foot	Barrels Per Mile	Barrels Per Hour	Miles Per Hour	Feet Per Second
2	2.375	2.067	3.75	22	17	0.8	1.1
4	4.500	4.026	10.79	83	105	1.3	1.8
6	6.625	6.065	18.97	189	320	1.7	2.5
8	8.625	7.981	28.55	327	675	2.1	3.0
10	10.750	10.020	40.48	515	1,280	2.5	3.6
12	12.750	12.000	49.56	738	2,000	2.7	4.0
14	14.000	13.250	54.57	900	2,640	2.9	4.3
16	16.000	15.250	62.58	1,193	3,850	3.2	4.7
18	18.000	17.250	70.59	1,526	5,350	3.5	5.1
20	20.000	19.250	78.60	1,900	7,200	3.8	5.5
24	24.000	23.250	94.62	2,773	11,800	4.3	6.2

*Rounded-off Values

Source: Petroleum Extension Service, 1973, Tables 4.6 and 4.7. Data are for plain-end pipe. Weight includes threads and couplings. Flow characteristics are for weight 38° oil.

10 pounds per square inch (psi) per mile of length. For different products moved by a pipeline the flow characteristics will vary from those in Table VI-3.

To keep the fluid moving through the pipeline against the forces of friction, pressure must be continuously applied usually by means of a pump, although there are pipelines that use downhill terrain so that the liquid flows by gravity. Most pipelines handling petroleum or its derivatives operate at a pressure between 850 and 1400 psi. To provide a safety margin, equipment used is generally that specified by American National Standards Institute (ANSI) as the 600-pound series, rated at a maximum operating pressure of 1440 psi (Association of Oil Pipelines, 1974). Viscosity of the liquid itself, pipe roughness, terrain features and other factors influencing the degree of friction, cause the pressure to drop at a continuous rate as the liquid flows through the pipeline; the amount of the drop is expressed in psi per mile of pipeline distance.

Pressure is interrelated with flow rate and pipe size by the formula given in the Appendix. Increasing the pressure (for a given pipe size) does not increase flow rate proportionately. Raising pressure by 10 percent leads to only about 5 percent increase in flow. The typical relationship between flow rate and operating pressure is shown in Figure VI-4 (Association of Oil Pipelines, 1974).* Pressure required to achieve a given flow rate varies inversely with pipe diameter, and a decrease in the pipe size results in a disproportionately great increase in pressure requirements (Petroleum Extension Service, 1973).

In very short pipelines, especially if the terrain is favorable so that the flow of liquid is aided by gravity, it might be possible to supply all the pressure needed at the starting point. But the situation is seldom so favorable and pipelines usually require one or more additional stations at points along the way. The total number of pumping stations required is determined by the overall pressure drop between starting and end points of the line (product of the length of the pipeline in miles times the pressure drop in psi per mile, adjusted for differences in elevation of the end points, reflecting the effect of gravity). The ratio of this pressure drop to the operating pressure (rounded up to the next highest whole number) gives the number of pumping stations, including the one at the beginning of the line.

In perfectly level terrain, the booster stations would be evenly spaced. However, there are usually differences in elevation along the line that affect the distance at which the continuous pressure drop will result in the need for new pressure. On stretches of the line that run upgrade, distances between booster stations are less than on level ground and where the flow is downgrade so as to be aided by gravity, pumping stations can be even farther apart. As a rule of thumb,

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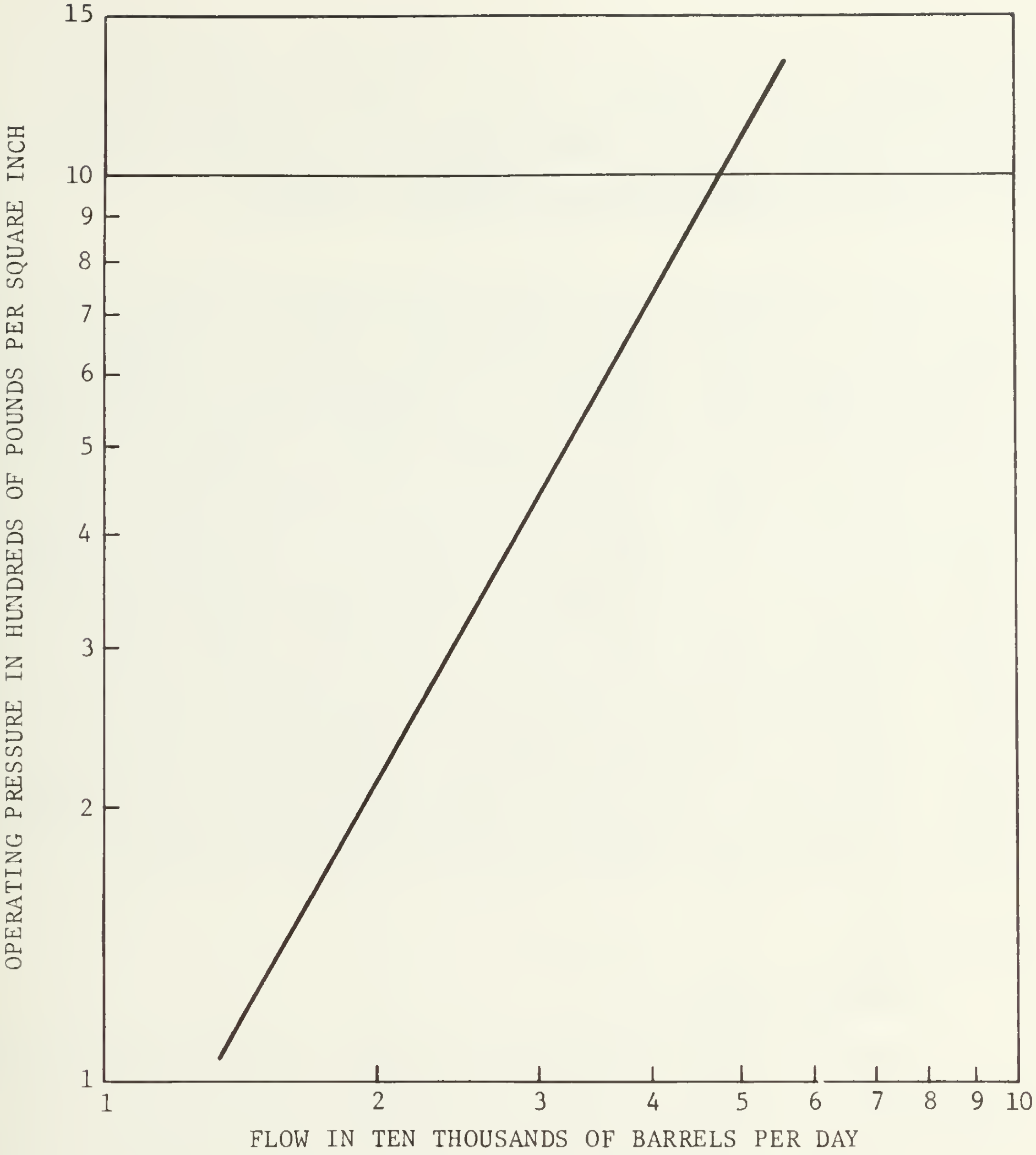
*It should be noted that the figure is representative only and the specific product in the pipe is not identified in the source.



Note: The data as presented by the source is representative only and is not identified as to petroleum product or pipe size.

Source: Association of Oil Pipe Lines, 1974.

FIGURE VI-4

TYPICAL CURVE OF OIL FLOW VERSUS PRESSURE booster stations often average about 30 miles apart (Association of Oil Piplines, 1974). However, they may be much more widely spread, with considerable variation in distance. On a pipeline crossing Oklahoma and Missouri from Cushing, Oklahoma to Wood River, Illinois, the five stations are situated at intervals ranging from 72 to 101 miles (Petroleum Extension Service, 1966).

For gas pipelines, the relation between pressure and pipe size is given by the formula in the Appendix by which it is seen that as the ratio of wall thickness to outside diameter of the pipe increases, the pressure applied inside the pipe also increases. In practice, the allowable pressure in a pipeline also depends on the strength of the steel used and the pipe design. Representative data for pipe sizes are shown in Table VI-4. It should be noted that this table gives the pressure at which the pipe would yield. The operating pressure would never be more than 72 percent of the value shown for a given pipe size and weight. Gas typically moves at rates of 10 to 25 miles per hour (Federal Power Commission, 1974). The rate of flow increases with increasing pipe diameter, other parameters remaining the same. Compressor stations are required at points in the line to maintain an adequate pressure level. The National Gas Survey of the FPC considers 50 to 100 miles or more to be a typical range of separation between compressor stations. Dimensions for typical compressor stations are given in Table VI-5. The total area required would be considerably larger. Compressor stations are normally enclosed within a fenced area containing piping, valves, and other auxiliary equipment.

Reliability

Transmission Lines

In the broad sense, power-line reliability refers to having adequate electric power available whenever necessary. It is not based on the maintenance or failure of a single transmission line, but on redundant paths for power transmission, adequate reserves, and the capability to draw on these through interconnections of a grid. All U.S. electric utilities have subscribed to minimization of the effects of an outage on all lines in a ROW. In emergencies resulting from failure in part of the system, it may be necessary to overload an alternate line. A typical criterion for reliability is the ability of the system to withstand an outage of any single transmission line (Aerospace, 1975).

Most Reliability Council Design criteria require testing a transmission network for the overlapping outage of two lines. Here, however, we are concerned with protection of the single ROW and outages of the line(s) on it. Transmission line outages may be classified as resulting from four types of causes (Federal Power Commission, 1971; IEEE-EEI Committee Report, 1967) as shown in Tables VI-6 and VI-7 (based on data from 1950-65). The tables show that, on the average, a powerline 100

TABLE VI-4

SELECTED PIPELINE DATA (GAS LINES)

OUTSIDE DIAMETER (inches)	WALL THICKNESS (inches)	WEIGHT (Tons/mile)	INTERNAL PRESSURE* (psig.)
12.75	0.250	88.12	1370
12.75	0.333	115.55	1810
14	0.312	120.60	1560
14	0.500	190.32	2500
16	0.375	165.21	1640
18	0.500	246.71	1940
18	0.625	277.00	2430
24	0.344	229.28	1000
24	0.500	331.29	1460
30	0.312	261.57	720
30	0.438	364.66	1020
36	0.375	376.68	720
36	0.750	746.00	1458
42	0.312	366.72	520
42	0.625	730.00	1040

Source: Gas Engineers Handbook, Industrial Press, Inc., 1969

*Pressure is derived by Barlow's formula (see Appendix) for 35000 psi minimum yield stress.

TABLE VI-5

TYPICAL COMPRESSOR STATION
DIMENSIONS
(in feet)

MAIN COMPRESSOR BUILDING			AUXILIARY BUILDING		
WIDTH	DEPTH	HEIGHT	WIDTH	DEPTH	HEIGHT
59	108	25	28	32	18
54	111	43	25	25	18
74	122	29	32	37	18
42	80	33	40	70	27

Source: Gas Engineers Handbook, Industrial Press, Inc., 1969. Data are representative of stations of 14,000 to 15,000 hp, powered by each of the four main types of prime movers.

TABLE VI-6

OUTAGES PER 100 CIRCUIT MILES PER YEAR

CAUSE OF OUTAGE	LINE VOLTAGES			AVERAGE FOR THE THREE CATEGORIES
	230 kV	287 kV	345 kV	
Natural Phenomena	0.68	1.834	3.459	0.99
System Operation	0.162	0.028	0.353	0.17
Line or Equipment Failure	0.068	0.037	0.129	0.07
Human Actions, Foreign Objects, Unknown	0.226	0.093	0.780	0.261
TOTAL	1.136	1.992	4.721	1.49

Source: Federal Power Commission, National Power Survey, Vol. I, 1971, Table 13-3; "Extra High Voltage Line Outages," IEEE-EEI Committee Report, IEEE Transactions in Power Apparatus and Systems, Vol. PAS-86, No. 5, May 1967.

TABLE VI-7

NUMBER OF OUTAGES

CAUSE OF OUTAGE	230-kV LINES		287-kV LINES		345-kV LINES		TOTAL ALL LINES	
	NO. OF OUTAGES	PERCENT	NO. OF OUTAGES	PERCENT	NO. OF OUTAGES	PERCENT	NO. OF OUTAGES	PERCENT
Natural Phenomena	996	60	196	92	510	73	1702	66.28
System Operation	236	14.2	3	1.4	52	7	291	11.33
Line or Equipment Failure	98	5.9	4	1.9	19	3	121	4.71
Human Actions, Foreign Objects, Unknown	329	19.8	10	4.7	115	17	454	17.68
All Causes	1659	100.0	213	100.0	696	100.0	2568	100.0

Source: Federal Power Commission, National Power Survey, Vol. I, 1971, "Extra High Voltage Line Outages," IEEE-EEI Committee Report, IEEE Transactions in Power Apparatus and Systems, Vol. PAS-86, No. 5, pp. 547-62, May 1967.

miles long would have an outage once or twice a year from all causes. Of greatest concern are failures produced by external events, which comprise nearly 85 percent of the total. Typical examples include breaking of a conductor from weight of accumulated ice, a fallen tree, impact from another object (such as an aircraft), tornadoes or windstorms. Lightning is the most frequent cause of failure, accounting for 42 percent of all outages in the sample surveyed. According to the sample surveyed, higher voltage lines are more prone to lightning outage. Transmission lines in the 345 to 360 kV class reported slightly over three outages per hundred miles per year, on the average. However, susceptibility to lightning outages actually depends on footing resistence. Since the time of the study, improved design can be expected to result in a lower rate of lightning outages in 345 kV lines. Outages may also occur, although less frequently, from collapse of a tower structure either as a result of external impact; snow or ice loading; or natural diaster, such as earthquake, fire or flood. An analysis of transmission line outages can be found in the IEEE-EEI Committee Report, May 1967.

Outages are classified as permanent or temporary. Permanent outages result from faults accompanied by some damage to the insulation or the structure of some line component so extensive that transmission cannot continue. The line must be taken out of operation and repairs made to the component(s) involved. Temporary outages result from faults that can be cleared up quickly by de-energizing the affected component through circuit-breaker or other switching action. In many instances, service can be restored in a matter of milliseconds by automatic high-speed opening to break the circuit and reclosing so that the outage is imperceptible to many of the users of the line (Eaton, 1972). A standard of recovery for the total system within 10 minutes of any transmission line outage has been set as a goal by the Western Systems Coordinating Council.

Serious consequences may result when outages occur that affect capability of the system to continue delivering power to major load centers. These can vary from leaving some portion of a population center without power for residential, commercial and institutional use to secondary consequences affecting interconnected networks by which a whole area may be blacked out (as happened in the metropolitan Northeast in November 1965). Industrial users may be dependent on continuous blocks of power to maintain processes that are costly to shut down and start up again. Institutions such as hospitals require continuous power to maintain equipment in continuous operation. The redundancy of the system in terms of alternate paths over which power may be switched when an outage occurs and the capability of emergency or standby power systems for industrial and institutional users affect how critical the outage of a given line may be.

Reliability is important in transmission line routing and assessment of potential impact from two points of view: (1) system redundancy in terms of providing alternate connected paths to transmit power to users may represent justification for the proposed power line and its location; (2) practices necessary to minimize the likelihood and consequence of line failures can affect the feasibility of ROW location and impact of the line.

To maximize system reliability in the case of damage to a line, parallel lines serving the same point(s) of a network must be spaced far enough apart so that damage to one is not likely to cause failure of the other. A separation of at least 2000 feet is often used as a minimum distance. During lightning storms, the danger of flashover, an electric discharge over the surface of an insulator, is minimized for overhead lines by using one or two ground wires. Typically, ground rods are used for spoil with resistivity 100 ohms per meter. With resistivity of about 1000 ohms per meter, counterpoise* is provided in the form of wires buried about two feet under the towers (Aerospace, 1975; Powel, 1955). The probability that lightning will strike a tower is directly related to the height of the tower (Powel, 1955). For underground lines, three lightning arresters are installed at overhead-underground transition points. These large porcelain units are hollow and contain a thyrite resister to reduce lightning surges to acceptable levels (Northeast Utilities, 1974b; 1975).

Pipelines

For pipelines, the important consideration is to keep the line functioning so as to meet delivery schedules. Unlike electric transmission, which involves a high degree of built-in redundancy and a capability for almost instantaneous switching to the use of alternate paths, a pipeline may typically represent a critical path. Reliability tends to depend on scheduled maintenance and early detection of faults so that they may be corrected before they impose major interruptions in delivery service. A major source of line leaks (accounting for as much as 20 percent of occurrences) in oil pipelines is earth-moving machinery used in subsequent construction projects near a pipeline (Association of Oil Pipelines, 1974).

To the pipeline operator, a major interruption in service represents a significant financial loss, especially if it occurs when the line is operating near its full capacity. Both shippers and consumers of pipeline products are usually geared to a delivery schedule. Interruption of this schedule interferes with production and with operations that depend on a continuing supply of the pipeline product. In particular, industrial operations that require oil, gas, or pipeline slurry as fuel or that use it as input (as for further refining) are dependent on stored reserves or on alternate delivery provisions if they are to avoid shutdown. Isolating a major population center from its normal supply of oil or gas represents a severe inconvenience that can pose a health hazard to residential customers as local reserves are exhausted. Electrical generating stations that rely on a pipeline product face curtailment of power output; effects on consumers may be more long-lasting than a transmission line outage and, hence, more serious in long-term consequences.

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*Counterpoise is the provision of drive rods and a static line at the tower footing to reduce resistance.

Washout, caused by swollen streams, floods, or erosion problems, can damage pipes or leave them exposed and vulnerable to disruption. Improved surveillance by helicopters and low-flying aircraft provides a prime means of protecting the reliability of pipelines. Deeper burial and posting of warning signs can reduce the danger of inadvertant rupture from subsequent construction activities.

Safety

Safety of a utility line is closely related to reliability in that both considerations concern the prevention of accidents. Whereas reliability is primarily concerned with the effects on the line's capability to continue delivery, safety relates to the danger that may exist for property damage or injury to members of the public.

Safety factors are directed at avoiding adverse consequences to property or persons from two types of untoward events:

a. Continuing malfunction of the line either as a result of improper design or unforeseen internal failure.
b. External accidents such as impacts and natural phenomena, as noted in the preceding subsection.

Some of the same precautionary measures can be employed from the standpoint of both reliability and safety. For transmission lines, these measures include designing the line according to safety standards related to clearance, insulation, and grounding; for pipelines, depth, compaction, proper materials, and corrosion protection represent important routine safety precautions. Minimizing the potential for damage or injury from accidents or breakdowns in utility lines is important. This consideration provides one reason for routing lines so as to avoid population centers not directly served by the line.

Transmission Lines

The standard structure clearance to provide protection against flashovers (sudden surges of voltage causing an arc from a conductor, as may be induced by lightning) as prescribed by the National Electrical Safety Code is 10 feet plus 0.4 inches kV (Aerospace, 1975). The degree of separation provided between conductors has an important effect in preventing accidental electrocution of raptors and other large birds. Although quite a problem with distribution lines in the past, such wildlife destruction is little evidenced on lines having phase conductors spaced as much as 12 feet apart, as in transmission lines (Boeker, undated).

With the advent of EHV and UHV transmission lines (345 kV and above), design personnel must consider the possibility of certain electrostatic effects as a potential hazard to humans and animals on or near the right-of-way because of the electric fields emitted. Lower voltage transmission lines will not present a problem due to these effects.

Electrostatic effects are evaluated in terms of the induced current, voltage, and energy, each of which must have limitations for a particular situation with respect to the applicable line geometry and voltage level. The voltage gradient at ground level is usually taken as a design quantity since high values can produce discomfort to people walking or standing under a transmission line. Nominal voltage gradients at ground for typical existing and prospective UHV transmission lines are as follows:

Voltage (kV)	Gradient (kV/m)
345	5
500	7
765	10
1000	13
1300	16

Tests on humans have shown the threshold of sensation to be around 15 kV/m (IEEE, 1971). The ground gradient will decrease as the line height increases and the distance from the outermost conductor increases. The maximum gradient occurs approximately five feet from the outside phase at midspan and decreases significantly at the edge of the right-of-way. Proper clearances and line design will eliminate all potential hazards.

Another potential hazard due to electrostatic fields could be currents induced onto long fences, vehicles, or large ungrounded metal objects located near a high-voltage transmission line. In a theoretical situation, current will flow through a person's body to ground when he touches an ungrounded object. The amount of current which will flow through the body depends on the size of the object or vehicle and its proximity to the line. Design is based on a current limitation of five milliamperes which is the minimum value whereby a small child will be caused physiological harm. Lower-valued currents will not produce harmful effects but may be painful or annoying. Each situation must be considered on an individual basis and any hazard can be eliminated by proper grounding of the metal object.

Voltage may be induced in nearby utility facilities such as pipelines, railroad tracks, and communications equipment. Since induced voltages could create shock hazards or corrosion, each problem is treated individually during the design process and coordination between the various utilities eliminates any potential problems. Only a d.c. transmission line will cause corrosion. If there should be explosive or highly combustible vapors such as gasoline fumes or gas from a pipeline leak nearby, the current from induced voltage represents a potential danger of igniting these. Serious danger to individuals could result from coming in contact with transmission lines broken or downed by an accident. The potential hazard is, of course, reduced by locating lines in remote areas where there are few people. Conversely, lines so placed that they could fall across buildings or other structures near human habitation or across transportation thoroughfares increase the chance of personal tragedy. In practice, however, the danger is minimized by the protective features built into a transmission system through relays and circuit breakers. Typically, the system is divided into protective zones separated by circuit breakers. If a fault occurs in any system component in a particular zone (such as a break in the line), protective relays determine the existence of the fault and circuit breakers disconnect that zone from the system. (Westinghouse, 1964). Normally, a conductor breaking will trigger a circuit breaker to open within 60 milliseconds, whereas one second is required for the conductor to fall 16 feet.

Pipelines

The principal danger with pipelines is from leaks or breaks in the line. Pipelines may split as a result of undetected weak spots or excess pressure. They may rupture from external damage, such as caused by earthquakes, floods, landslides, or lightning. As noted above, improperly supervised construction activities represent one of the most frequent causes of breaking buried pipes. Escape of the pipeline contents poses a danger to persons as well as to property. Explosion from leaking gas, although now rare, is a particularly serious form of accident.

For pipelines carrying liquids, any uncontrolled spilling, no matter what the rate of escape, is deemed an emergency (Petroleum Extension Service, 1973). Spilled oil poses a hazard from the danger of fire and from fumes. Pipeline spills or leakage can represent a source of contamination to freshwater used for drinking purposes and a hazard to wildlife.

New pipelines are designed, built, tested, operated and maintained in accordance with strict Federal regulation, as prescribed in CFR Part 192, administered by the Office of Pipeline Safety (U.S. Department of Transportation, 1973). These standards have eliminated most of the problems which have occurred in the past. For example, pipelines are tested to a pressure above that at which they will operate, in order to eliminate weak spots. As a further precaution to prevent excess pressure, over-pressure protection is required. Coating and provision of cathodic protection largely prevents corrosion, as discussed below.

Corrosion of pipelines increases the hazards of leakage by weakening the pipe. External corrosion is an electrochemical reaction. In buried pipelines, corrosion typically results from chemicals leached into the groundwater which then becomes an electrolyte permitting the flow of current from one metallic conducting surface (anode) to another (cathode). This is similar to the process that occurs in electroplating, in which the metallic ions are deposited on the cathode. This electrolytic reaction takes place when two pipes of dissimilar metals are installed adjacent to each other. It also occurs between different parts of the soil. Corrosion can be inhibited by coating pipes with protective substances that insulate pipelines from ground currents, but these gradually wear away.

Cathodic protection provides the principal means of protecting against damaging corrosion. Continuing adequate cathodic protection has been called "the most important single item in preventive maintenance of pipelines" (Petroleum Extension Service, 1973). The principle of cathodic protection is to supply, from an outside source, electric current that flows through the soil toward the pipe rather than away from it--thus making the pipe itself a cathode. The need for cathodic protection makes a pipeline more vulnerable to adjacent power lines and affects the feasibility of shared utility corridors (which are discussed in Section VII on Shared and Multiple Use.

Explosions as a result of pipeline operations can occur when pipelines are emptied for maintenance. Pipelines containing a mixture of air and oil vapors or other gas could explode if accidentally ignited within partially enclosed piping. The danger is especially great with crude oil pipelines. To guard against such accidents, cutting of the pipe by mechanical means is recommended, rather than by oxyacetylene blowtorch, which can ignite the explosive mixture. An inert gas (e.g., nitrogen or carbon dioxide) can also be forced through the pipes to dilute or eliminate the combustible vapors (Petroleum Extension Service, 1973). For pipelines containing only gas, however, cutting with an oxyacetylene torch involves no danger and is standard industry practice (Pacific Gas and Electric, 1975).

RIGHT-OF-WAY DIMENSIONS

Length of Line Segments

Except perhaps in the shortest utility line that can be planned as a single stretch linking two end points, a corridor is formed as a sequence of individual segments. Straight-line shortest distances between end points and essential intermediate connections would, other things being equal, represent minimum cost paths. This situation may be modified by the greater costs of building through specific terrain conditions. Environmental considerations may also prevent direct paths between two adjacent points of the line. For all these reasons, individual segments represent alternative pathways of running the line or corridor between two sequential points that must be on the line. For example, there may be only one feasible point (B) where a line may cross a body of water, approach a government preserve, or enter a difficult terrain after leaving a location (A) serving a particular user. There may be several possible paths between A and B, each comprising an alternate segment.

The distance in miles of a given segment of the line or corridor is an important measure both for determining line routing and in assessing environmental impacts. The impacts are partly a function of the extent of the corridor in terms of how many miles of the environment will be affected.

Because it will involve less of the environment than will a longer segment and, if approximately the same environmental conditions prevail, a shorter segment will have less impact. As already noted, the variable costs of a line--which are far higher than the fixed costs--are essentially a linear function of length. Thus, making a segment longer will increase its cost, as shown in Tables VI-8 and VI-9. The actual per-mile costs can be expected to vary with local conditions and to have changed considerably in the past few years, especially as the result of inflation. The tables are particularly intended as an indication of the relative rates, which are less changeable factors.

ROW Width

The width of the ROW could affect the amount of land available for other usage; however, if the ROW is non-exclusive, it may be used for other compatible purposes as discussed in Section VIII. Width also affects the esthetics of the line, since the visual impact of a wide swath in the landscape is--other things being approximately equal--greater than that of a narrow swath. Width must be adequate for the structures required by the capacity of the line, for maintenance access and for safety factors. Power line widths are also influenced by the need to minimize noise effects and radio-TV interference from corona.

Power Lines

Horizontal Dimensions (Width). For an electric transmission line, the width of the ROW must be at least that required to provide adequate clearance for the conductors. Thus, width is influenced to some degree by line voltage. It is also determined by many other factors. These

TABLE VI-8

INDICATION OF RELATIVE COSTS OF TRANSMISSION LINES

AVERAGE COST PER MILE IN THOUSANDS OF 1972 DOLLARS

TRANSMISSION VOLTAGE AND TERRAIN	WOOD POLE	CONCRETE POLE		STEEL		UNDERGROUND CABLE ONE CIRCUIT
	SINGLE CIRCUIT	SINGLE CIRCUIT	DOUBLE CIRCUIT	SINGLE CIRCUIT	DOUBLE CIRCUIT	
115 kV	$42-62	$110	$145	$71	--	$332
230 kV Rolling Terrain	72	--	--	82-90	$116	675
230 kV 50% Rolling, 50% Mountainous		--	--	92-102	129	
(DC)±375 kV Rolling Terrain	--	--	--	142	--	--
(DC)±375 kV 50% Rolling, 50% Mountainous	--	--	--	155	--	--
525 kV Conventional Deadends	--	--	--	242	--	--
525 kV Rolling Terrain	--	--	--	172-227	--	--
525 kV 50% Rolling, 50% Mountainous	--	--		189-235	--	--

Source: Bonneville Power Administration, information used for planning purposes only.

TABLE VI-9

INDICATION OF RELATIVE PIPELINE COSTS

PIPELINE DIAMETER	AVERAGE COST PER MILE (THOUSANDS OF 1972 DOLLARS)
12 Inch	$45
16 Inch	65
20 Inch	100
30 Inch	170
36 Inch	330

Based on line-completed costs reported in FPC

Source: The Aerospace Corporation, "Technical Compatibility Factors for Joint-Use Rights-of-Way," prepared for Bureau of Land Management, U.S. Department of the Interior, 1 February, 1975.

include safety and maintenance, tower configuration, and the requirement to minimize radio and TV interference as well as audible noise. The phase configuration also affects the width of a ROW; a flat configuration is wider than a delta configuration. The extent to which the lines sag between pole structures (which for level spans will be maximum at the midpoint) and the degree to which they will swing in the wind are also taken into account. Trees must be cleared a distance on either side of the center line determined by the electrical clearances necessary to protect against flashover or falling on the line (see Figure VI-5). The standing tree clearance varies with the line voltage. Clearances used by the Bureau of Reclamation (to which an allowance must be added to account for 10-year growth of the particular trees involved) are given in Table VI-10. Growth potential of the trees is also considered in determining which ones need removal to provide falling-tree clearance.

Typical ROW widths for transmission lines are shown in Table VI-11. Sag distances are discussed under vertical dimensions of the ROW in the next subsection.

Clearances

The height of a transmission line reflects the requirements to protect the line from interference and the consequence of accidents. In overhead electric transmission lines, adequate clearance from the surface must be provided. There are standard clearances where a line crosses over a thoroughfare, another utility, or a bridge or other structure. Typical clearance values are listed in Table VI-12. These are intended to be representative only; it is recognized that interpretation of minimum standards varies.

As a result of their weight, conductors sag between the upright structures that support them. The amount of sag on a given structure varies with a number of factors, including temperature, and sag calculation for specific conditions is a rather complicated engineering determination. Details can be found in standard handbooks (Standard Handbook for Electrical Engineers, 1968; U.S. Department of Agriculture, Rural Electrification Administration, 1972; U.S. Department of the Interior, Bureau of Reclamation, 1967). In a practical situation, the sag is specified by the supplier of the conductors to be used on the line. As a rough rule of thumb, the sag in spans between 750 and 1200 feet can be taken at from two to six feet per 100 feet of distance (Powel, 1955). An approximation of the sag (S) expected in a conductor between towers at the same elevation can be calculated from the following formula (U.S. Department of Agriculture, 1972):

$$S = \frac{L^2 w}{8h}$$

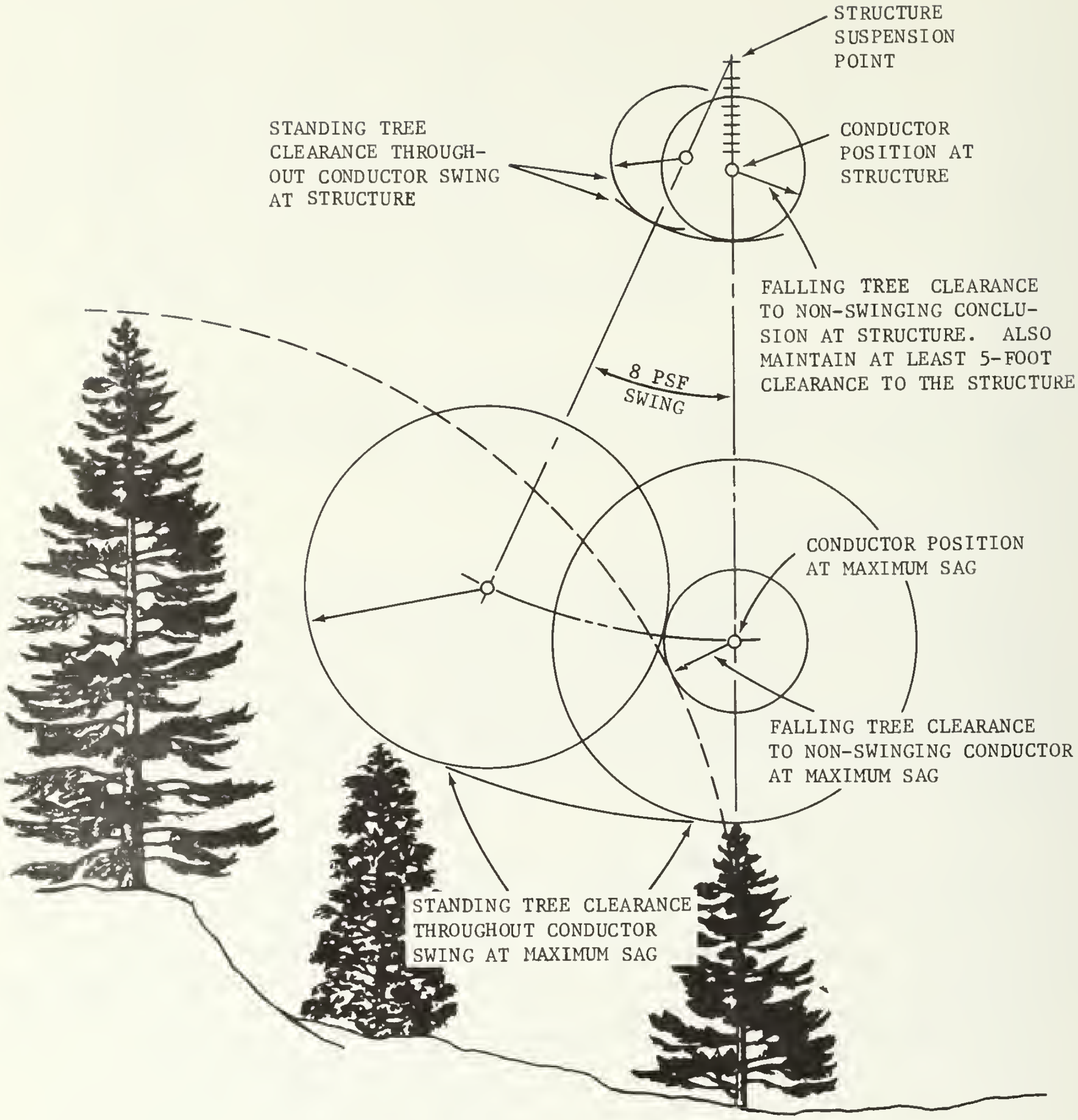

STRUCTURE SUSPENSION POINT
STANDING TREE CLEARANCE THROUGHOUT CONDUCTOR SWING AT STRUCTURE
CONDUCTOR POSITION AT STRUCTURE
FALLING TREE CLEARANCE TO NON-SWINGING CONCLUSION AT STRUCTURE. ALSO MAINTAIN AT LEAST 5-FOOT CLEARANCE TO THE STRUCTURE
8 PSF SWING
CONDUCTOR POSITION AT MAXIMUM SAG
FALLING TREE CLEARANCE TO NON-SWINGING CONDUCTOR AT MAXIMUM SAG
STANDING TREE CLEARANCE THROUGHOUT CONDUCTOR SWING AT MAXIMUM SAG

FIGURE VI-5

BONNEVILLE POWER ADMINISTRATION
DANGER TREE CLEARANCE CRITERIA

TABLE VI-10

STANDING TREE CLEARANCES[1]

Line (kV)	Wood Pole Lines				Steel Tower Lines			
	Minimum Conductor		Span (ft)	Conductor Clearance (ft)	Minimum Conductor		Span (ft)	Conductor Clearance (ft)
	Size	Stranding			Size	Stranding		
69	No. 4/0 AWG	6/1	700-1000	10.0				
115	266.8 MCM	26/7	700-1000	10.7				
138	477 MCM	24/7	700-1000	11.1				
161	477 MCM	24/7	700-1000	11.6				
230	954 MCM	45/7	700-1000	13.0	954 MCM	45/7	1000-1400	13.0
345					954 MCM (two)	45/7	1000-1400	15.3
500					954 MCM (three)	45/7	1000-1400	19.0
765[2]					954 MCM (four)	45/7	1000-1400	23.7

Source: United States Department of the Interior, Bureau of Reclamation, personal communication, May 1975.

[1] These clearances reflect the National Electrical Safety Code clearance to buildings. They are valid for elevations not exceeding 3300 feet above sea level. They are deemed to have sufficient margin to compensate for increased sag at unbalanced icing conditions or accelerated conductor temperature under heavy electrical emergency loading conditions.

[2] V-strings all phases.

TABLE VI-11

TYPICAL ROW WIDTHS

Line Voltage (kV)	Typical Width Requirements (feet)
115/138 (a.c.)	90-150
230 (a.c.)	150-170
345 (a.c.)	135-200
765 (a.c.)	200-225
±400 (d.c.)	140-150

Sources: Northeast Utilities System, Overhead Transmission Policies and Practices, 1974(a)

U.S. Department of the Interior, Bureau of Land Management, The Need for a National System of Transportation and Utility Corridors Across Federal Lands, A Study Report, Vol. I (Draft), 1 July 1975.

TABLE VI-12

VERTICAL CLEARANCES FOR TRANSMISSION LINES

(in feet)[a]

TYPE OF CROSSING	NOMINAL LINE-TO-LINE VOLTAGE						
	115 kV	138 kV	161 kV	230 kV	287 kV	345 kV	500 kV
Ground, Pedestrians Only	17.6	18	18.5	19.8	20.9	22	25
Public Streets, Alleys, Roads	22.6	23	23.5	24.8	25.9	27	30
Railroads	30.6	31	31.5	32.8	33.9	35	38
Buildings (Clearance in any direction with light wind)	11	11	12	13	14	15	18
Communication, Messenger and Trolley Wires	6.6	7	7.5	8.8	9.9	11	14
Guy and Lightning Protection Wires	4.6	5.0	5.5	6.8	7.9	9	12
Other Power Lines:[b]							
0 - 50 kV) — Ungrounded	4.6	5.0	5.5	6.8	7.9	9.0	12
69 kV)	5.2	5.7	6.1	7.4	8.5	9.7	12.6
69 kV)	4.6	5.0	5.5	6.8	7.9	9.0	12.0
115 kV)	5.1	5.6	6.0	7.4	8.4	9.6	12.5
138 kV)	-	6.0	6.5	7.8	8.9	10.0	13.0
161 kV) — Grounded	-	-	6.9	8.2	9.3	10.4	13.4
230 kV)	-	-	-	9.6	10.7	11.8	14.8
287 kV)	-	-	-	-	11.1	12.9	15.9
345 kV)	-	-	-	-	-	14.0	17.0
500 kV)	-	-	-	-	-	-	20.0
750 kV d.c.[c]	-	-	-	-	-	-	16.5

[a] Clearances for upper conductor at maximum sag, no wind; lower conductor at 60° F. initial sag, no wind.

[b] Clearances are based on line to line effective voltage for an ungrounded circuit and line to ground effective voltage for a grounded circuit.

[c] Clearance for 750 kV d.c. are based on equivalent a.c. voltage to ground of 184 kV.

Source: U.S. Department of the Interior, Bonneville Power Administration, Informal notes on NESC Standards (6th Edition) 1975.

where L = length of the span in feet,
w = weight of conductor in pounds per foot;
h = horizontal tension for which the conductor is designed in pounds.

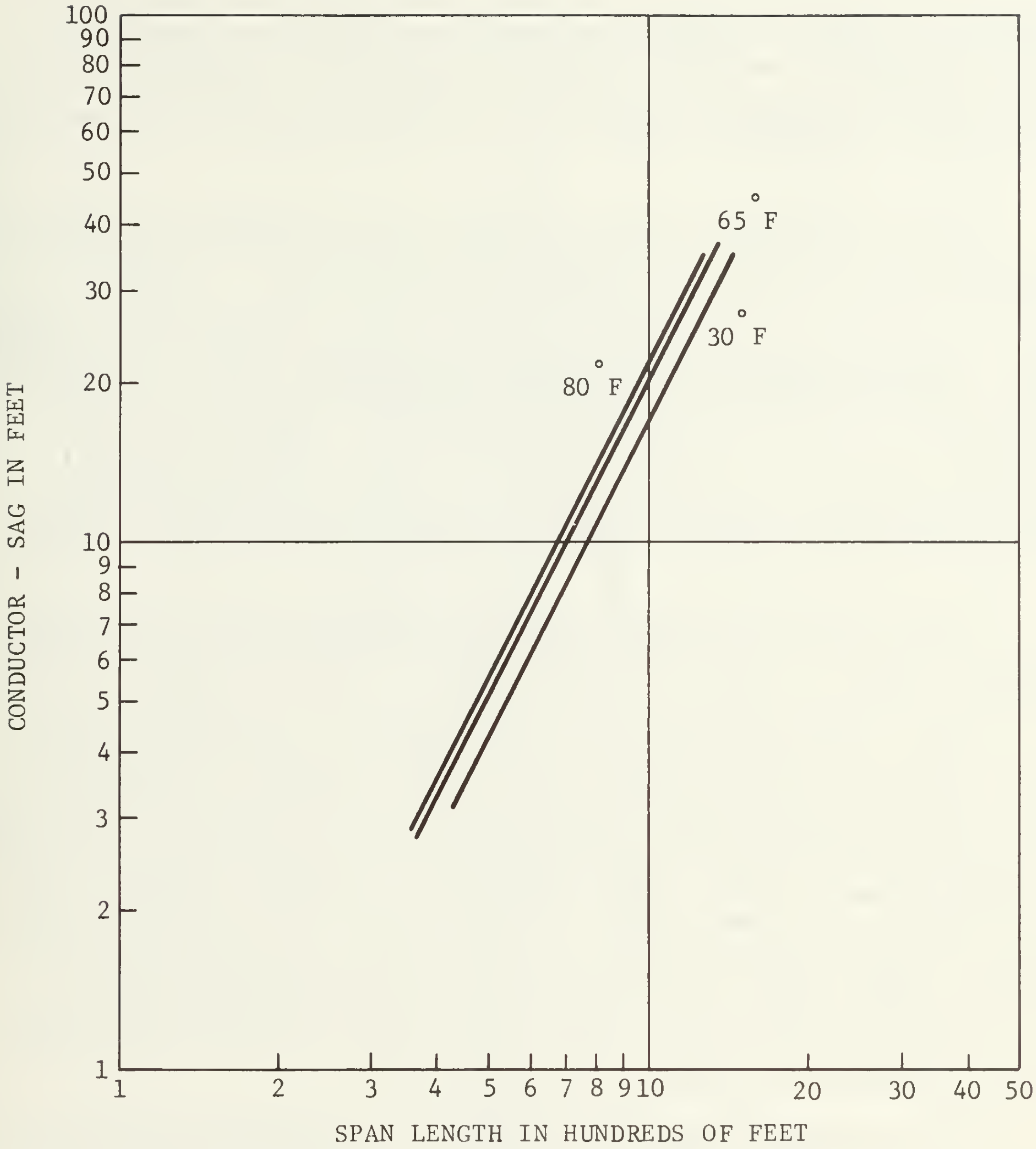
Typical sags at a range of temperatures are plotted in Figure VI-6. The data are for medium loading under conditions of 1/4 inch ice, 8 pound wind, with a 700-foot span and are derived from a chart by the Aluminum Company of America.

Although calculation of sag distances is not part of the environmental assessment of a transmission line, an appreciation of the nature and magnitude of sag can be important in considering the suitability of a particular routing and the impact of clearance requirements on such features as shared or multiple ROW use.

Structures

The number and type of structures, the span, and the extent of sag in a given length of overhead transmission line are influenced by economics as well as by considerations of safety and stability. The high cost of structures makes long spans economically desirable, but there are tradeoffs in the greater expense of taller towers, increased pulling tension and other factors, while the maximum acceptable sag distance and length of span impose constraints. On level terrain where there are no crossing problems and spans can be equal, the number of structures in a given stretch of line can be determined as the ratio of distance to length of span (rounded upwards to the next integral value). Where the terrain slopes or is markedly uneven, shorter spans may be necessary for some portions of the distance so that a larger number of structures must be emplaced. However, in uneven terrain, it may be possible to use hillocks to locate the upright structures so that sag (over the lower ground) produces less of a constraint and longer spans are possible. Sometimes, additional support is required for crossing a draw or narrow valley in a single span and a lighter structure is positioned between the two main towers.

Structures used on overhead transmission lines can be classified from several points of view. The material is usually either wood or metal, although concrete is sometimes used. Steel is the predominant metal. Aluminum towers are coming increasingly into use; they are more costly but are also more resistant to corrosion. Wood structures are cheaper and easier to emplace; however, they are less durable. The Bonneville Power Administration has recently expressed difficulty in obtaining sufficient quantities of poles of suitable quality for use under conditions that prevail in the Northwest, for which Douglas fir is principally used. Metal towers are much sturdier as well as longer lasting, requiring less frequent inspection and giving maximum life with minimum maintenance. They require a foundation for emplacement.



Source: Department of the Interior, Bureau of Reclamation Design Standards No. 4, Power Systems, Office of Chief Engineer, Denver, Colorado, 1967.

Note : The data are for medium loading under conditions of maximum of 1/4-inch ice, 8-pound wind, with a 700-foot span. Taken from a chart by the Aluminum Company of America.

FIGURE VI-6

REPRESENTATIVE SAG DISTANCES AS A FUNCTION OF SPAN LENGTH

They are now generally used on transmission lines above 138 kV and are essential on higher voltage lines (500 kV or greater) to support the heavier conductors required. Wood structures are characteristic of lower voltage lines, particularly for distribution. Historically they were used on transmission lines up to 230 kV and their use was extended to lines up to 345 kV.

From the standpoint of how conductors are attached, structures may be tangent or dead-end. In tangent structures, the conductors are suspended from the insulators (see Figures VI-7 to VI-13). Tangent structures are used over staight stretches on the line. Angle suspension towers may be employed at points where the line deviates in a small angle (Standard Handbook for Electrical Engineers, 1968). In dead-end towers, the conductors are fastened rigidly to the structure (Figure VI-14). EPA practice is to use dead-ended structures for angles in the line greater than about 6° where the suspension clamp would not provide enough stability. For special support as may be required for long spans across water bodies, dead-end towers may be provided as backup to the suspension tower placed on each bank nearest the water's edge.

Tower shapes may be characterized principally as poles; special cross-strutted structures, termed descriptively H-frames and K-frames; (Figures VI-10, 11, 12) and lattice towers. They may be guyed, as shown in Figure VI-13. Poles, H-frames and K-frames may be either of wood or of metal, whereas lattice towers are normally constructed only of metal sections bolted together. The characteristics of the structure may influence the number per mile and, hence, the span. Bonneville Power Administration (BPA) standards for wood poles call for about eight H-frames per mile under average conditions, with span length accordingly averaging some 750 feet; single poles with cross-arms attached, which are taller than H-frames, run about 20 per mile, with an average span length between 270 and 280 feet. Longer spans are more easily facilitated by metal structures--other things being approximately equal--than by wooden poles. At one time, the average range nationwide was from about 750 to 1200 feet (Powel, 1955), but now spans of 1500 feet are not uncommon (Aerospace Corporation, 1975).

The relationship between tower height and permissible length of span is complex, and depends not only on the type of vertical structure and conductor used but also on terrain and other local conditions determining the stress to which the line will be subjected from such factors as wind and ice loading. Obviously, the point of maximum sag in a long span calls for taller structures to provide the necessary vertical clearance at that point. However, since long spans impose a greater stress than shorter spans on the line--taller structures tend to be more vulnerable because of their higher center of gravity. For wooden poles used on the lower voltage transmission lines, the horizontal span limit varies inversely with pole height because of height limitations imposed by wind loading. This feature is illustrated in Table VI-13 which lists typical values prescribed by the Rural Electrification

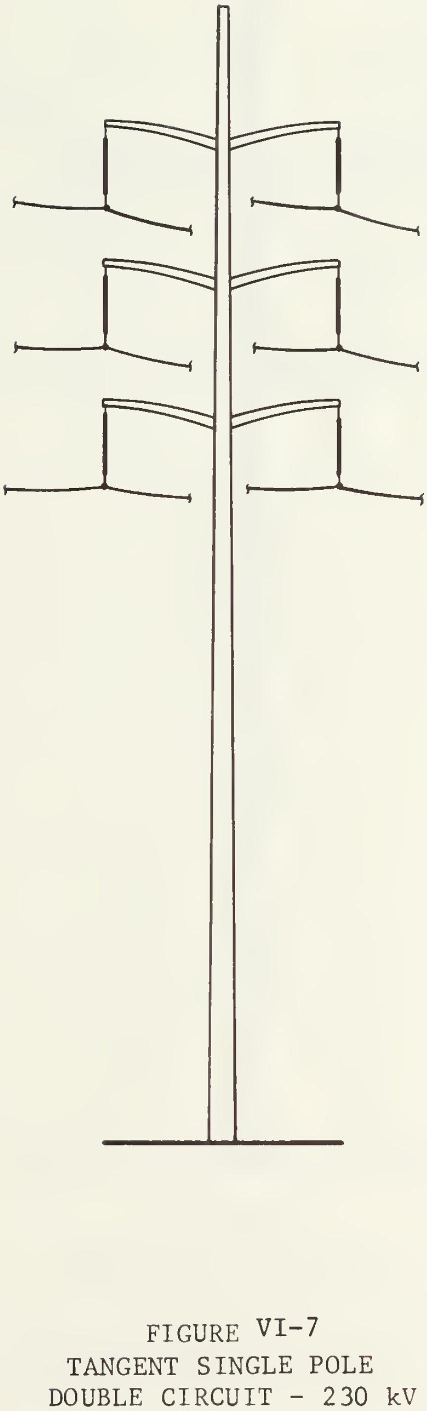


FIGURE VI-7
TANGENT SINGLE POLE
DOUBLE CIRCUIT - 230 kV

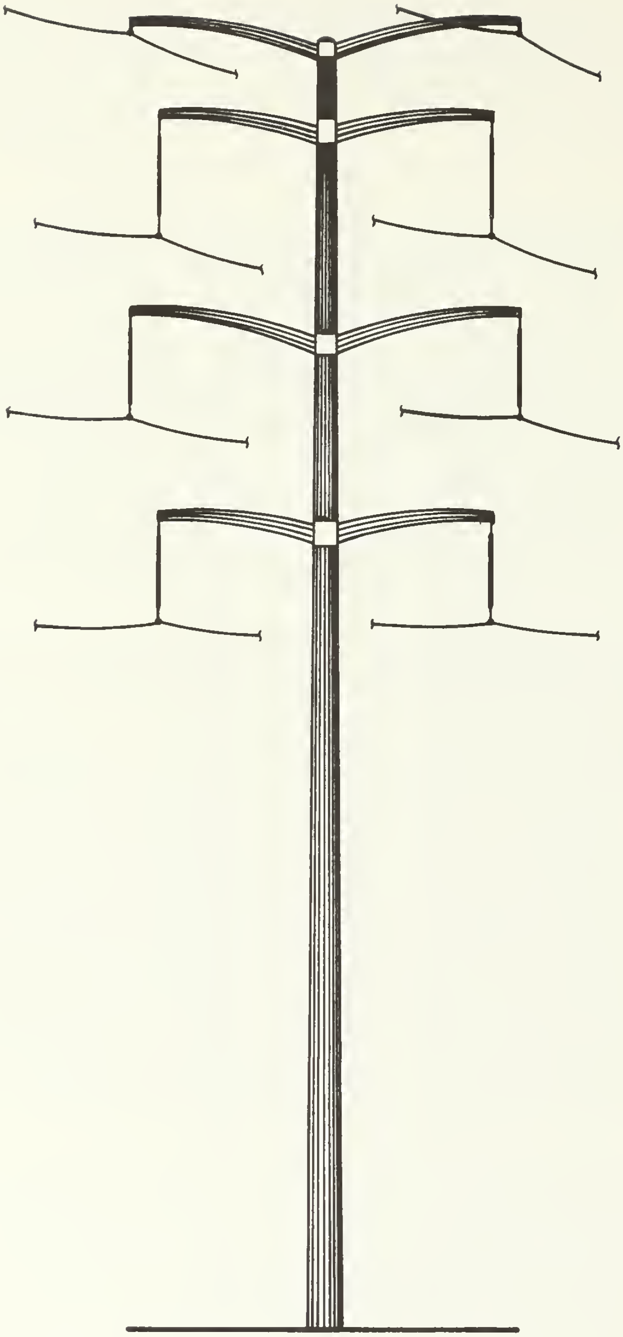


FIGURE VI-8
TANGENT SINGLE POLE,
DOUBLE CIRCUIT - 345 kV

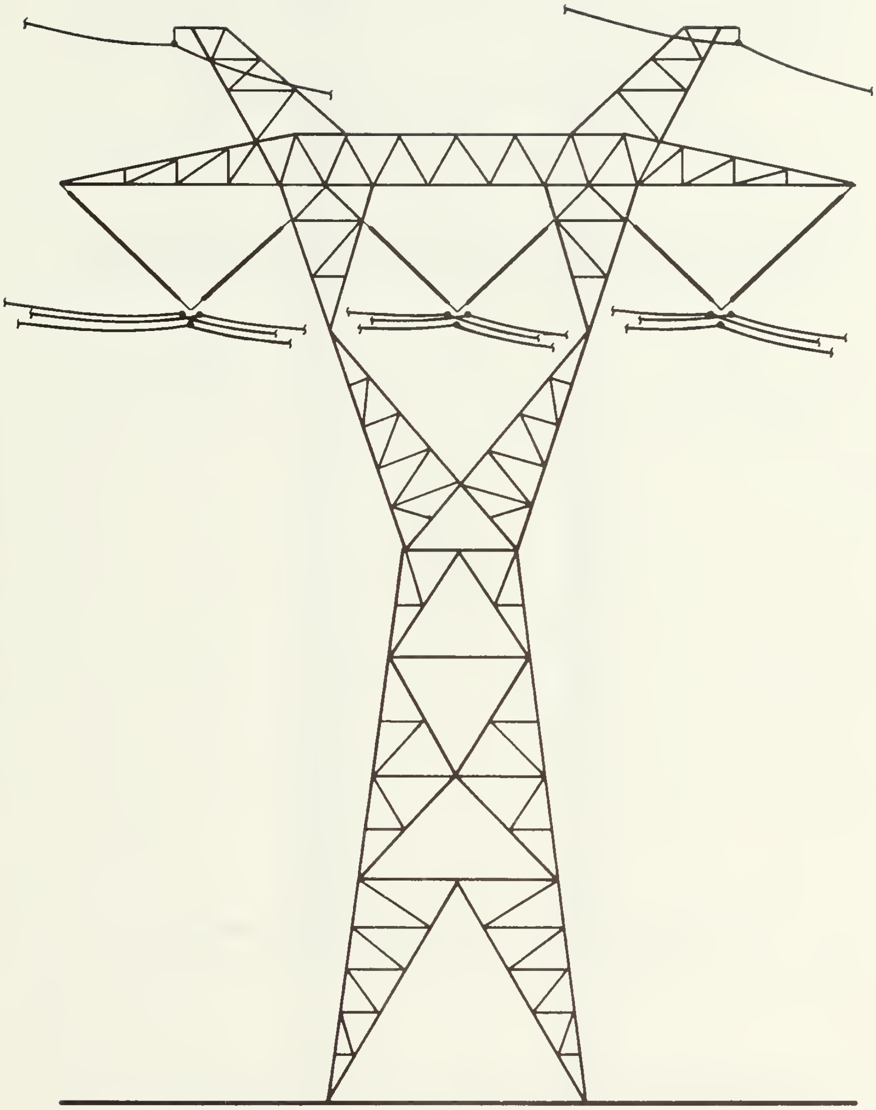


FIGURE VI-9
TANGENT LATTICE STRUCTURE,
SINGLE CIRCUIT - 500 kV

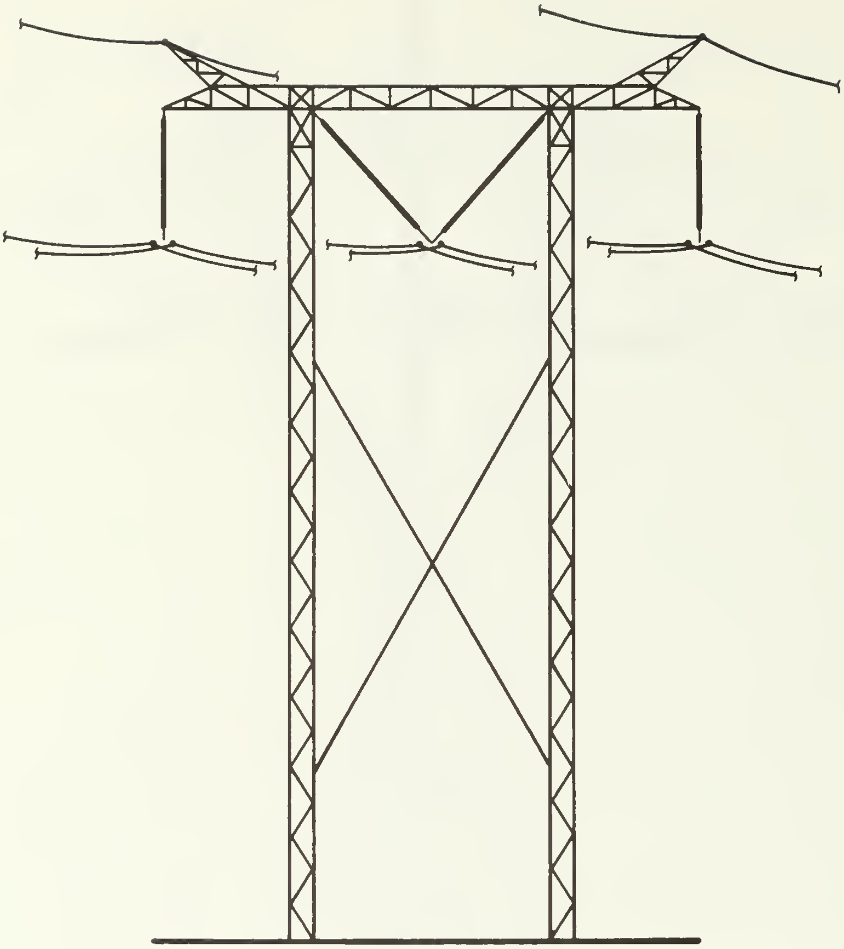


FIGURE VI-10
TANGENT H-FRAME,
SINGLE CIRCUIT - 345 kV

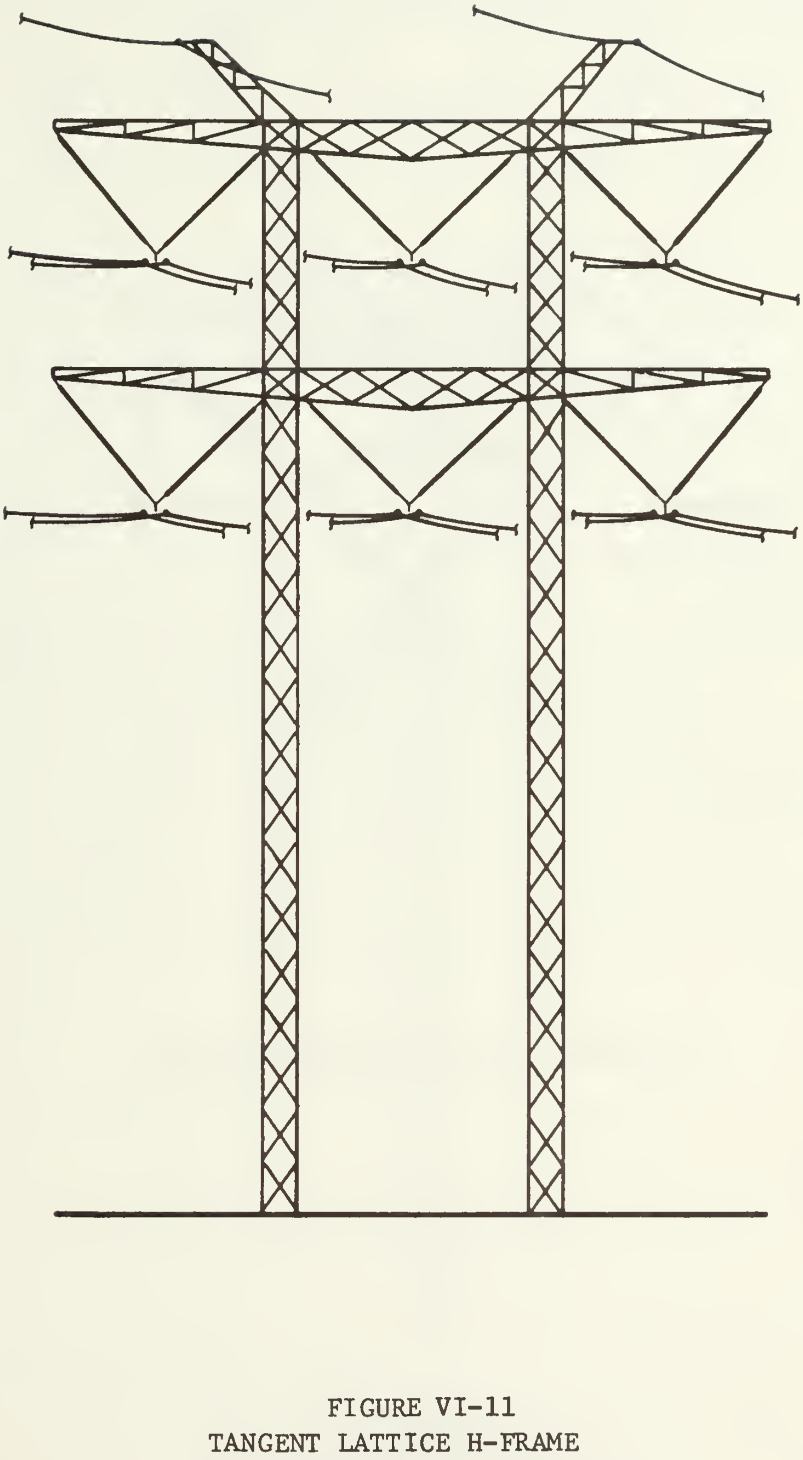


FIGURE VI-11
TANGENT LATTICE H-FRAME
DOUBLE CIRCUIT - 345 kV

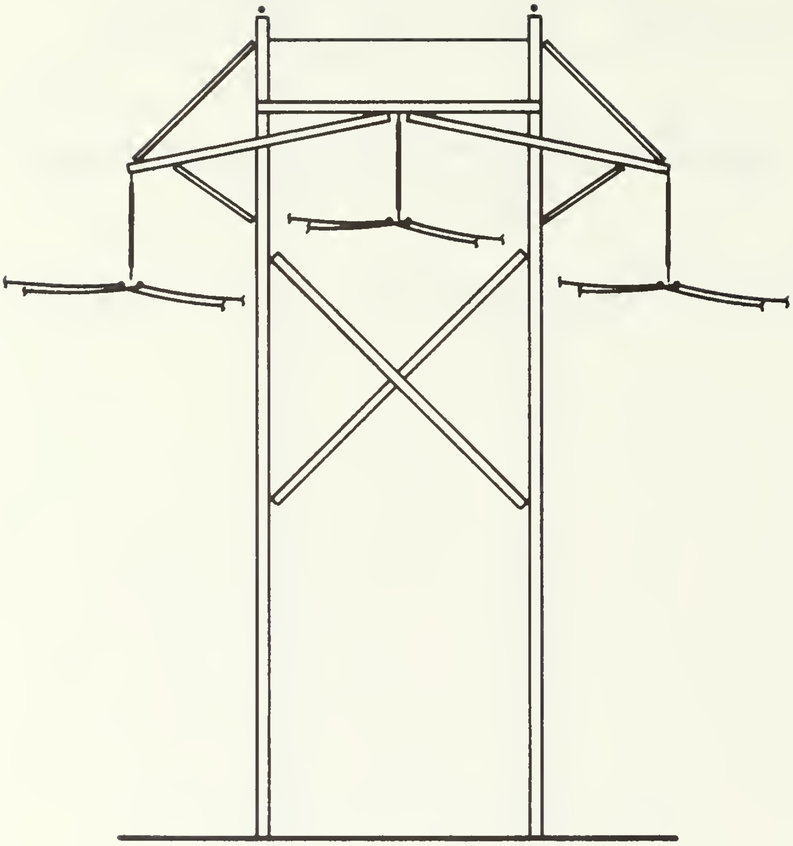


FIGURE VI-12
TANGENT K-FRAME
SINGLE CIRCUIT - 345 kV

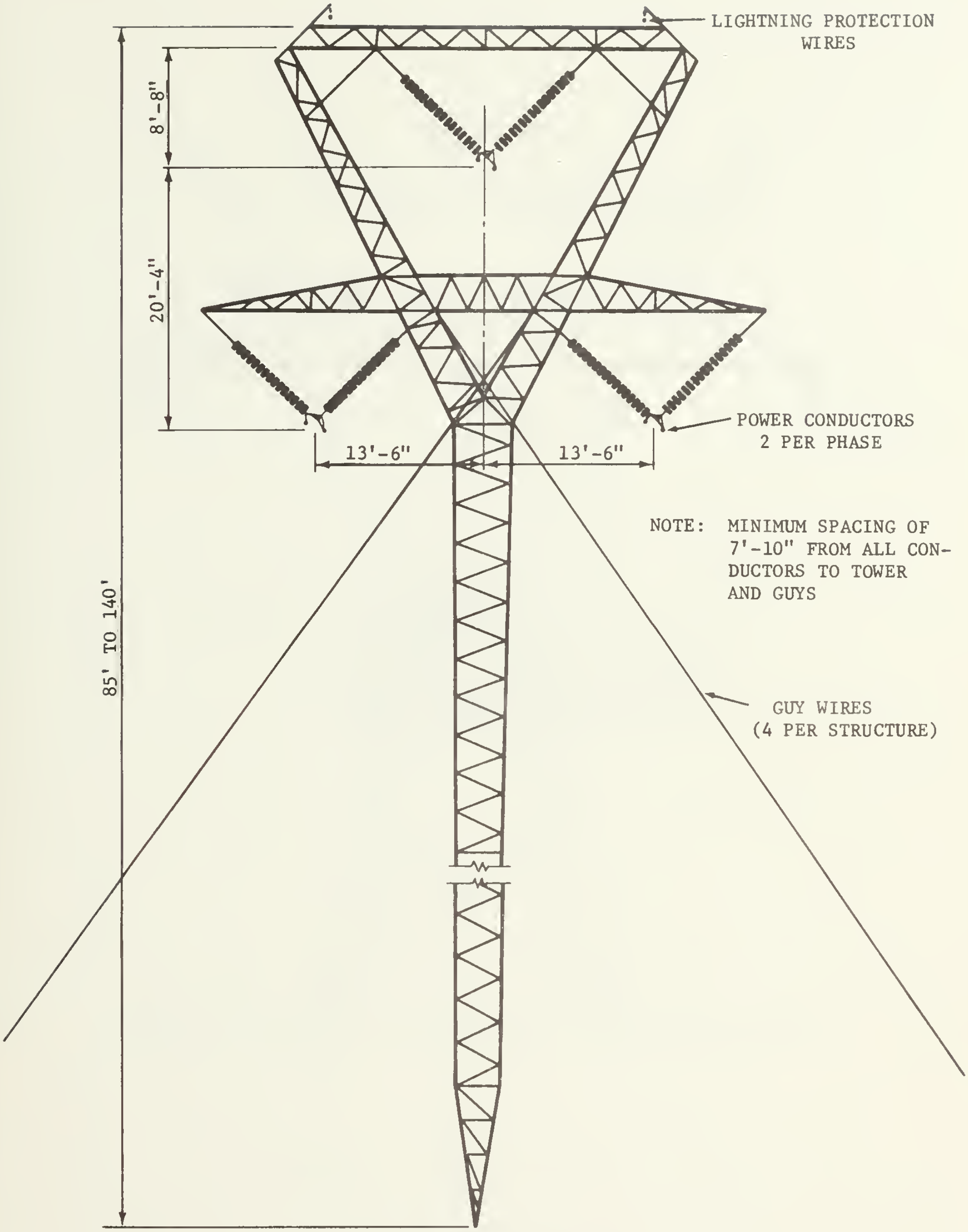

LIGHTNING PROTECTION WIRES
8'-8"
20'-4"
85' TO 140'
POWER CONDUCTORS 2 PER PHASE
13'-6"
13'-6"
NOTE: MINIMUM SPACING OF 7'-10" FROM ALL CONDUCTORS TO TOWER AND GUYS
GUY WIRES (4 PER STRUCTURE)

FIGURE VI-13
GUYED LATTICE TANGENT STRUCTURE
SINGLE CIRCUIT—345 kV

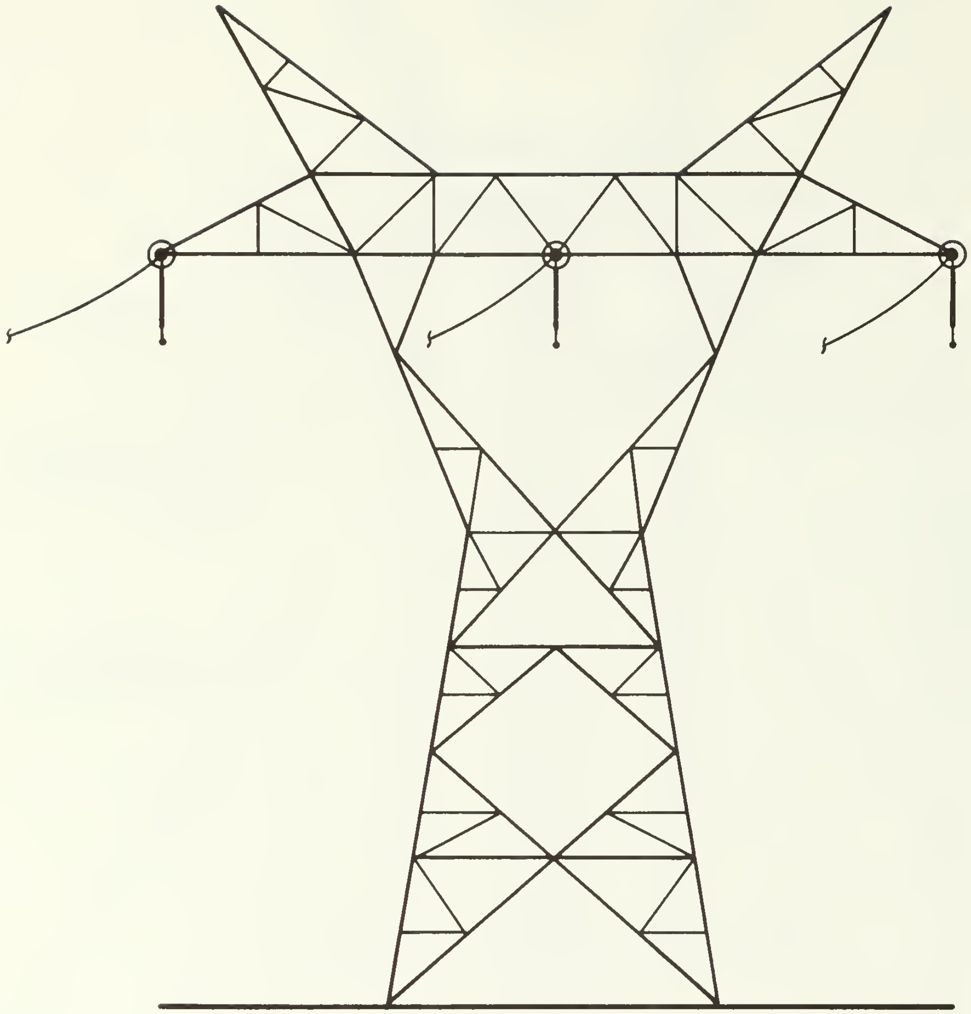


FIGURE VI-14
DEAD-END LATTICE STRUCTURE
SINGLE CIRCUIT - 230 kV

TABLE VI-13

SPAN LENGTH IN FEET RELATED TO HEIGHT AND CLASS OF WOODEN POLE

POLE HEIGHT (Feet)	CLASS OF POLE 1	2	3
40	909	751	612
45	880	732	577
50	864	697	552
55	829	672	536

Source: U.S. Department of Agriculture, Rural Electrification Administration, Transmission Line Manual, REA Bulletin 62-1, September 1972.

Administration for medium loading districts for various classes of wood poles. Actual span lengths will vary with the number and size of conductors supported. Loading districts are classified as light, medium, or heavy, depending on the load imposed in that region by ice, wind and snow. The medium loading district includes nearly all of the 11 westernmost states. Poles are classified by the American National Standards Institute (ANSI) in terms of capability to withstand the force of a given weight exerted two feet from the top of the pole. A discussion of pole classes is beyond the scope of this report. Details may be found in ANSI Manual 05.1, Wood Poles, Specifications and Dimensions for, 1972.

Self-supporting metal towers are of much sturdier constuction and can withstand the stress of conductors that would make wooden poles of equivalent height liable to topple. They can be provided in taller heights to give the vertical clearance required for long spans. It is not possible to tabulate or represent graphically the relationship between height and span length because it is influenced by too many other factors.

The type of tower structure employed has important impacts on the ROW dimensions and the costs. Dead-end structures have the most significant effect on costs of a power line, as they may be from 5 to 10 times more expensive than equivalent suspension towers. Consequently, the more angles required in a ROW, the higher will be the cost. Single poles have the advantage of being narrower than the other types of structures so that for relatively low capacity lines they can reduce the ROW width requirements by as much as 10 percent. Bulkier structures may, however, be able to transmit larger amounts of equivalent power and in many situations will be more efficient. H-frames are the least expensive among the three types in their capability to support the larger conductors. Other advantages of H-frames include low height and compatibility with rural surroundings. However, their breadth tends to impose requirements for a wide ROW. Lattice towers are tallest, but their structure gives maximum strength in proportion to amount of material used. The variation in height among the different structures is illustrated by the representative values listed in Table VI-14 (Northeast Utilities, 1974a; Land Plan Systems, 1974). The influence of structure type on ROW width and per mile costs (in 1972 dollars) has previously been illustrated in Tables VI-8 and VI-9.

To support lines next to highways or over such crossings as rivers, guard structures or temporary wood poles are used during stringing operations in addition to the structures providing the basic support at each end of the span.

TABLE VI-14

TRANSMISSION STRUCTURE HEIGHTS

STRUCTURE TYPE	VOLTAGE (kV)			
	115	230	345	500
Lattice - Single Circuit	-	77	85	95
Lattice - Double Circuit (Delta)	-	77	105	125
Lattice - Double Circuit (Vertical)	75-125	110	120-140	125-150
H-Frame - Single Circuit	55		55-100	88
H-Frame - Double	55		100	-
K-Frame - Single Circuit	-	40	65-75	-
Single Pole - Single Circuit	65-115	86	-	-
Single Pole - Double Circuit	65-115	100	125	-

Source: Northeast Utilities System Companies, *Overhead Transmission Policies and Practices,* 1974(a).
Landplan Systems, Commonwealth Associates, Inc., *EHV Transmissionline Routing Manual, Minnesota,* February 4 - June 1, 1974.

Underground Transmission Lines

Although underground transmission lines are not common because of their great expense, they have been used in some instances, particularly in congested urban areas. Submarine lines have also been laid where there would be technical problems in crossing large bodies of water.

Underground transmission lines use copper or aluminum as conductors that are then provided with insulation, typically in the form of oil impregnated paper tapes, rubber, or some synthetic such as polyethylene. For the usual three-phase alternating current, three insulated conductors are fitted into a steel pipe that may be 10 to 12 inches or more in diameter (Northeast Utilities, 1974b). The pipe is commonly in lengths of about 40 feet prior to welding and emplacement in a trench.

The pipe is typically filled with oil to provide additional insulation. The oil must be kept under pressure at about 200 psi by operation of pumping stations to prevent voids that would lead to ionization, eventually damaging the insulation. Pumping stations contain not only the pumping equipment, but as much as 35,000 gallons of oil in tanks.

One of the principal problems with underground transmission lines is conductor heating. Electrical insulation also provides thermal insulation. The earth in which the lines are buried also offers a much greater obstacle to heat dissipation than does the air. Much larger conductors are therefore required than for overhead lines of equal capacity. Also, reactor stations are required aboveground. Reactor stations provide equipment to offset the charging currents that develop in insulation as a result of capacitance when the alternating voltage is applied to the line. For 345 kV-lines, reactor stations are typically required about every 15 miles.

In some instances, self-contained cables utilizing oil impregnated paper pipes for insulation are employed instead of pipe-type cables. Self-contained cables are in the form of a hollow conductor serving as an oil duct. Small openings enable the oil to penetrate into the paper insulation. These cables provide more effective heat dissipation because the conductors can be installed with a separation between them. They also obviate the need for oil pumping equipment. However, they are little used in the United States, principally because they require extensive lengths of trenches to be kept open over the period required for emplacement.

Underground transmission lines are seldom used because the cost is generally prohibitive. As shown in Table VI-8, the cost of an underground cable may be nine times that of equivalent overhead circuitry for lines at or below 230 kV. Technical problems and attendant costs are much greater at higher voltages. It has been estimated that, at higer voltages, the cost of an underground line in rural areas is about 19 times that of overhead facilities providing equivalent capacity (Federal Power Commission, 1971). A study made in 1971 (updated in 1973) for Northeast Utilities Systems (1974b) of comparative costs for a specific 40-mile 345-kV line estimated that an underground line of 1000 MVA capacity would cost approximately $83 million. This figure was 15 times the cost of an overhead line of equivalent capacity using wood H-frame structures to carry a single circuit. The actual cost ratio of underground to overhead transmission varies widely, depending on the conditions of a specific project. It is significant also that much larger consumption of non-renewable resources is involved in undergrounding than in providing overhead lines. For example, the same study showed that over ten times as much steel would be required in providing the required power by an underground line. Some 3600 tons of oil was estimated by the study to be needed for underground cables; significant amounts of fuel are required in underground lines as contrasted with none for overhead transmission (Northeast Utilities, 1974b). Other considerations of undergrounding must include continuous trenching versus spot excavations for foundations, disposal of the soil dug up, and the trucking in and placement of thermic sand.

The long-term future of underground transmission may be enhanced by technological developments. Recognizing the growing pressures for more extensive use of underground cables, in 1970, the Electric Research Council of the industry sponsored a $17 million underground transmission R&D project. The techniques investigated to provide transmission capability at lower costs more nearly competitive with overhead lines include compressed gas insulation (CGI) systems and cryogenic and superconducting cables. The possible availability of underground lines using these techniques is foreseen by about 1980. CGI systems involve lower charging currents with reduced dielectric losses and provide superior heat removal capabilities. As a result, CGI cable may be able to achieve three to four times the capacity of the pipe-type cable now commonly used (Federal Power Commission, 1971).

Cryogenic and superconducting transmission would make use of the fact that electrical resistance of a metal is drastically reduced at extremely low temperatures. Cryogenic power systems might be designed to operate at temperatures as low as 4° K (-269° C). Systems using cooled normal metals are often termed "cryoresistive." Two possibilities which have been studied in some detail are cryoresistic-tape insulated systems using pressurized liquid nitrogen at temperatures around 80°K and the cryoresistive high-vacuum-insulated system. A system using niobium plated on copper as the superconductor with liquid helium serving both as the insulator and the cooler has also been studied (MITRE, 1974).

Requirements for Pipelines

For pipelines, the width requirements are greatest during construction. Not only must the trench be provided for, but the pipe must be laid alongside it before burying; accommodation is also required for heavy earth-moving and pipe-laying equipment. After construction, less width during operation is needed. The ROW must be wide enough to mark the centerline. During operation, actual clearance requirements frequently range from 10 to 25 feet, for ease of observation and access in detection of leaks. Typical widths for pipelines of common sizes are shown in Table VI-15.

When pipelines are set in ditches, the depth is typically about two and one-half times the pipe diameter. Deeper burial is sometimes provided as a measure of protection against disturbance, particularly by earth-moving equipment in large projects. When it is necessary to pass under another underground structure, the depth must be determined so as to give a satisfactory clearance, typically at least one foot.

Steel is generally used for trunk pipelines that deliver large volumes of material. It typically has to be coated to protect against corrosion. Representative data on pipe sizes and properties have been given in Tables VI-3 and VI-4. When the pipe may be subject to very severe corrosion conditions, resistive alloys may be used, but are precluded for general use by their high cost. For low pressure pipelines, steel substitutes such as extruded plastic, glass fiber or asbestos cement may be used. Lengths of pipe to be joined together range from 40 through 68 feet up to as much as 80 feet (Petroleum Extension Service, 1966).

Gas pipelines are supplied with valves generally placed at distances of from 5 to 20 miles apart. These typically result in structures that appear a few feet aboveground to provide ready access for opening and closing the valve. The significance of valves in assessing the environmental impact is in terms of the occasional visibility they provide to an otherwise buried facility.

SPECIAL REQUIREMENTS

Different types of utility lines have special requirements that can affect the choice of routing or the suitability of a particular design option. Some of these have already been noted in other connections. Booster and compressor stations required to maintain pressure for pipelines delivering liquid and gas have been considered in the subsection on transmission parameters. Depending upon the area they occupy, the requirements for construction and maintenance and the noise generated represent potential sources of environmental impact and may pose problems of compatibility for a proposed location. These stations have their own electrical requirements with attendant problems.

TABLE VI-15

TYPICAL ROW WIDTHS FOR PIPELINES (SINGLE USE RIGHT-OF-WAY)

PIPELINE DIAMETER (Inches)	SOIL TYPE	RIGHT-OF-WAY WIDTH		DISTANCE BETWEEN CENTERLINES (feet)
		SINGLE LINE (feet)	TWO LINES (feet)	
24	Normal	75	87	43
24	Rocky	75	106	62
48	Normal	100	114	54
48	Rocky	106	124	64

Source: Aerospace Corporation, Technical Compatibility Factors for Joint-Use Right-of-Way, prepared for the Bureau of Land Management, U.S. Department of the Interior, February 1975.

The lines required may be esthetic obtrusions and can pose a danger to raptors. Cathodic protection required for pipelines has been discussed under "Reliability." The special lightning protection provided to overheat electric transmission lines in the form of overhead ground wires and ground rods or wires sunk under the tower structures are features of both reliability and safety, as are the lightning arresters required for underground lines.

For pipelines, control stations are an important part of their operation, enabling a central office to monitor through a control panel the performance of the line and its associated equipment. Telemetered data supplies information from distant points about such matters as pressure maintained in the line, flow rate, pump performance, and tank capacity. This automated control procedure generates requirements for a tie-in with microwave and telephone communications and for process control computers that can operate with remote data input.

Petroleum pipelines require tank farms at major input and delivery points as well as at switching centers, where products are transferred from one line to another. These tank farms may be extensive, requiring the acreage to accommodate tanks with a total storage capacity running into millions of gallons. Tank farms have important implications for esthetic impact and may be judged incompatible with the surroundings, whereas the buried line itself will be inoffensive even in a wilderness area or within easy view of a residential district. There is also a potential hazard to safety in the concentration of volatile and highly flammable liquids. The excavation and earth-moving operations necessary in tank farm construction must also be given special consideration as to their potential impact for erosion, siltation, and disturbance to the hydrology of the region.

Underground electrical transmission involves special requirements which contribute to making this mode less attractive than overhead lines from a cost and engineering standpoint. The problem of dissipating the heat as a result of resistance inherent in the conductors has already been noted. Typically, the conductors are wrapped in oil-soaked covering within pipes that are buried in a trench surrounded by thermic sand (to a distance of about a foot on either side), having the property of conducting heat at a faster rate than the solid in which the trench is dug. Special requirements include large porcelain units called "potheads" at junctions between overhead and underground transmission. Potheads are essential for control of voltage stress.

INTERNAL COMPATIBILITY

Many of the interrelationships that prescribe the internal compatibility among individual features of a utility line have been noted in previous subsections. These include pumping pressure matched to flow rate and pipe size; substations providing transformers to step up electric voltage for transmission or step it down for distribution; and the tradeoff inherent between tower height and span length for overhead transmission. There are also interfaces within the line which must be provided for. These include transition points between locations of a line underground and above the surface; connections between components of different sizes; and, at a more detailed level, internal clearance requirements among the structures of an overhead transmission line. While these seldom have any significant effect on the impact of a line or on the suitability of a proposed routing, they may become considerations in some situations.

At various points, a pipeline may have to emerge from underground to cross a body of water or a very sharp drop in terrain. Whether such a crossing is more efficient than going underneath the interruption is an engineering determination in each situation and, in general, the decision is likely to favor boring under; however, when a crossing occurs, the potential for impacts may be somewhat different than when the line is underground. It is possible that special precautions may be necessary to prevent significant erosion around the point where the pipeline enters or emerges from underground; to ensure that emplacement of support structures does not seriously impact on topsoil and vegetation if on land or induce scouring if set in water; and to provide a degree of permanence in any platform structure that carries the pipe, so that it does not wash away or collapse as a result of stress from severe weather conditions.

The same natural and physical factors affect the degree of stress to which the pipeline and the environment will be subject at the transition points as throughout its length. It is well to remember that there are conditions that might intensify the potential impacts. The point of emergence from the ground creates a partial exposure providing somewhat more vulnerability to erosion and soil loss than exists where the line is fully buried with topsoil restored and vegetation providing a measure of protection. Consideration of conditions of the river bank such as soil quality, as well as the flood levels under recurrent weather conditions are necessary in assessing the effect of boring through the banks or sinking vertical support structures at the shoreline.

Scouring is a particular problem produced by the movement of sediment at critical current rates so as to deepen the level of the river bottom. It may take place around a vertical structure sunk into the stream bed, as a result of the eddying effect induced in the current flow at that point by the structure. Where the stream bottom consists of loose, viable material, a velocity as low as 0.8 feet per second may be enough to produce scouring. For coarser material, the critical velocity is 1.5 feet per second. An engineering determination should be made of the possibility of scouring. The need for possible preventive measures as indicated, for example, in the Civil Engineering Handbook (Urquhart, 1959) such as construction of special pilings, should be considered.

It may sometimes be necessary to change the diameter of the pipe used, whether in expanding an existing line with pipe of a larger capacity; in using a larger and stronger pipe at some critical point, such as a crossing; or for some other reason. When this occurs, no problem affecting the potential environmental impact or the routing of the line is likely to be involved. Typically, the joining of two different size pipes can be accomplished by an underground connection termed a "swage." Where structures above ground may be used in rare situations, these are not likely to pose any impact problem, since they are small, with largest dimensions in the range of 10 to 15 feet.

For underground transmission of electric power, junction points with overhead lines are the points at which potheads and lightning arresters (previously noted in the subsection on underground lines) are located. The esthetic impact of these potheads and lightning arresters needs to be considered in relation to the surrounding landscape and the exposure to visibility. While smaller than a substation, these objects have a somewhat bulky appearance that could afford a source of complaint. In wooded regions where the terrain is suitable, such structures may be blended readily into the landscape; their location can be chosen to take advantage of rises in ground and they can be at least partly screened by appropriate vegetation.

In overhead transmission lines, clearances required between conductors and supporting structures are a part of providing the necessary insulation level. This clearance distance is required to eliminate or minimize flashovers due to over-voltages, fault voltages, and surges from switching and similar transient conditions or from lightning. Typical clearances between the conductors and supporting structures as prescribed by the Bonneville Power Administration have been presented in Table VI-12.

Incorporation in Prior System Right-of-Way

Because the requirements of a utility line seldom remain the same throughout the life of a system, it sometimes happens that the utility is faced with the need to expand capacity within the existing ROW. This may involve augmenting the facilities of the current line, replacing them with others that transmit more power or deliver greater quantities of fluid, or adding a second line. The choice of how to provide greater capacity is an engineering consideration based on the cost/benefits of the various alternatives. There are obvious advantages in merely adding to existing facilities. In pipelines, the practice of adding one or more parallel lines connected to the main line is known as "looping."

Replacement of facilities in place is likely to mean interruption of service over the line and would not often be the option selected. The decision to construct a whole second line would be expected when current and projected demands represent a significant multiple of those presently being met by the existing facilities.

Pipelines are more easily augmented in capacity than are electric transmission lines. As seen above, pipeline capacity is a partial function of pressure, and installing more pumping capability can increase pipeline capacity. Short of duplicating the entire line, additional loops can be installed for all or part of the route.

If an existing line is to be duplicated with a parallel system serving the same points, it is often cheaper and preferable from the standpoint of other engineering considerations to include it in an existing ROW. There are obvious advantages in providing a ROW that will permit expansion to meet the demand for increased capacity in the future. From the utility's point of view, it may be less costly to add facilities on the same ROW, thus avoiding additional land acquisition and simplifying the engineering requirements of preparation. From an environmental standpoint, expansion in a cleared ROW can eliminate the potential impacts of developing another location. Thus, criteria for assessing alternative routings include the likelihood of future expansion if such a need arises.

In acquiring a ROW a utility may, with an eye to growth, obtain a multiple grant allowing additional lines to be added. A primary criterion is the existence of adequate space. Typical width requirements for accommodating two lines were illustrated in the subsection on ROW dimensions. In pipelines, the necessary width is constrained primarily by the requirements of 75 to 100 or 125 feet for construction, depending on pipe size. Width constraints on power lines are principally due to safety and reliability requirements for adequate space around conductors.

Requirements for compatibility in expanding an existing ROW may affect the assessment of alternatives to construction of a new line. Conversely, in an environmental report accompanying a proposal to meet increased needs by expanding the capacity of an existing line, there would be a question of establishing that the additions would not only be adequate for the purpose but could be accommodated on the present ROW.

The widening of a ROW is sometimes met with intense opposition from small landowners, who feel that while the first land taken was tolerable, losing the use of additional land will be critical to their operations. This possibility needs to be considered in weighing a widened corridor versus a distinct ROW in a different area. If it is not feasible to widen the existing ROW then, from the standpoint of visual impact, it is preferable to use a totally new location rather than to provide a separate corridor parallel and close to the first. Creation of a narrow hiatus area between two ROW boundaries should be avoided (U.S. Department of Agriculture, 1970). Also, as previously noted for transmission of electric power, reliability considerations are best met by a separation of at least 2000 feet between distinct lines serving the same points.

The decision to expand an existing ROW to accommodate a new line--particularly an overhead power line--involves a number of tradeoffs The width constraints resulting from the degree of separation imposed by safety factors have already been discussed. As noted above, these vary with the capacity of the line. Southern California Edison practice is that when more than two parallel 500 kV lines have to be accommodated, the additions should involve a separate ROW at a distance of at least 2000 feet (Southern California Edison, 1974). It should also be noted that, from an environmental standpoint, multiple lines may be a mixed blessing (Barber, et al.,1974). There comes a point at which the massing of structures and the conductors they support produce an adverse esthetic impact that is disproportionately great. Hence, while two and even three lines in a corridor are by no means unusual, it would be quite rare to find more than five.

CONSTRUCTION AND MAINTENANCE PRACTICES

Excavation

For transmission lines, clearing, grading and preparation of access roads are carried out first, followed later by excavation for towers. Wooden poles are merely set into holes, which are then filled and the soil compacted around them. Metal tower structures, however, require preparation of a foundation to which the legs of the tower are anchored. Soil borings are taken at the points where erection will be made. Foundations are most commonly steel grillage or concrete; the latter are either spread, with vertical or sloping piers, or drilled-in concrete caisson, which is used where the prevailing soil consists of stiff clays or granular materials suitable for drilling. Rock anchors may be used where suitable rock exists near the ground surface; a stub or heavy steel angle may be grouted into the rock (after drilling of a suitable hole) for attachment of the tower. For situations where the soil does not provide suitable foundation conditions, piles have to be driven (Bonneville Power Administration, American Society of Civil Engineers, 1970).

In backfilling, the excavated material is used where suitable. Topsoil should be segregated for replacement in position at the end of construction work.

Areas of unstable soil, prone to significant subsidence and especially to slides, represent exclusion criteria that should be avoided in excavations to emplace transmission line structures. Foundations can be provided, if necessary, in swampy, boggy lands, but since the work is quite expensive, these are avoided whenever possible. They require metal braces or "swamp shoes" sunk deep to anchor the structure and prevent tipping.

In restoring sites after tower erection, it is important to reshape and contour the soil around the foundation, both to minimize erosion and to maintain conditions compatible with the terrain. Compacted soil must be broken up to permit the development of ground cover. Especially where the land is part of a cultivated area, topsoil should be provided, being hauled in if necessary to restore pre-existing conditions. Seeding of the disturbed area should be practiced, except in cultivated land (Hellman, 1974). Where cattle may be grazing, it is especially important to clean up thoroughly so as to remove breakaway bolts or other pieces of hardware that might be swallowed by the animals--giving rise to what the Bonneville Power Administration terms "hardware disease."

For pipelines, ditching is significant and is regularly carried out by such mechanical equipment as ditching machines, backhoes, and power shovels. Drilling for emplacement of dynamite charges is typically required when a pipeline is to be placed in very rocky terrain. Depth and width of the excavation vary somewhat according to the dimensions of the pipe to be laid, as discussed in connection with ROW dimensions and structures, but typically are 1.5 or 2 times the pipe diameter (with a minimum width of one foot). There must be an allowance of 12 inches or more of cover. Deeper cover may be required where the pipe cannot conveniently be bent to fit the terrain. Sloping ditch edges are frequently provided to reduce crumbling of soil into the excavation.

Particular problems are encountered when pipe is laid in soil that has a low capacity for load bearing, particularly in water-saturated soil that moves like quicksand into an excavation to fill it up. In this situation, dewatering is necessary to stabilize the soil so that it can be excavated and the pipe can be laid.

In some conditions, double ditching in which the topsoil is maintained separate from the remainder may be required. This practice is followed in regions where the topsoil is fragile, requiring careful replacement to maintain the ecology (e.g., in tundra regions), or where the subsoil is undesirable material, such as rock or caliche, that should remain buried.

Of particular significance to the potential for environmental impact is restoration of the excavation. After backfilling, soil compaction is typically accomplished by means of a tractor or other heavy equipment. An important requirement is to minimize the danger that the filled earth will erode. Extra earth may be placed to create small diversion levees, especially on slopes. Bulkheads are sometimes needed to hold steep ground such as a river bank. In uneven terrain, terracing is often useful. Special fill material, including solid rock and mixed earth and rock, may be used. Seeding is regularly practiced to provide a quick cover that holds the soil (Petroleum Extension Service, 1973; Gas Engineers Handbook, 1969).

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Pipelines have successfully been laid in virtually all types of terrain, in river bottoms and underneath stream beds as well as in water-saturated soil, so that few exclusion criteria are likely to be encountered in terms of conditions that completely prohibit excavation. Because erosion and washouts by flood waters may expose pipelines and increase the probability of damage, it is obviously desirable to avoid floodplains and other areas of high erosion potential. In some situations, a determination may be made on engineering grounds that an underwater crossing is not feasible. An overhead pipeline crossing is then necessary, as discussed in the next subsection. Spanning may be preferred for small bodies of water, as well as for drainage ditches and ravines, as a means of avoiding the need for bends in the pipe or for deep burial. It may also be advisable to avoid diverting a stream of water during construction. On the other hand, overhead crossing may be precluded where the structure would be vulnerable to floating debris or to high water during the flood stage of a stream.

For underground transmission lines, the procedure of clearing, grading and excavation is similar to that required for laying pipelines. Typically, a trench is dug to permit emplacement of 40-foot pipe lengths that have been welded. The conductor cables are pulled into place within the pipe, over a length of about 3000 feet, with manholes provided through which the cables are inserted (Northeast Utilities, 1974b). It should be noted that the excavated material may not be suitable for replacement if the thermal conductivity is too low. Especially where the banks of a river to be crossed are subject to heavy rains, thicker walled pipe may be employed.

Crossings

Pipelines

In pipeline construction, underwater crossings are generally preferred to providing a suspension or supported crossing above the surface of a body of water. With care not to disturb the flow of water, a ditch in the channel must be prepared, frequently at a depth well below the level at which scouring can be expected to occur. Dredging must be carried out as part of the excavation and arrangements must be made for disposal of spoil. It may be necessary to weight the pipe, especially in bottoms where the soil forms a slurry with the water, thus increasing the pipe's buoyancy. The ditch may be filled with rock for additional stability. After initial emplacement, straps across the pipe may be anchored to the bed beneath the water to further hold the pipe in place. In navigable waters it is important to determine the degree of interference with navigation and to schedule construction so as to minimize interruptions to traffic. Especially where the banks of the river to be crossed are subject to erosion, thicker-walled pipe may be employed.

A new technique employing directional control of hole drilling permits boring for a pipeline to be placed under a river without digging, dredging or disturbing the surface between entry and exit. The equipment is manufactured to bore holes up to 17 1/2 inches, thus placing a limitation on the size of the pipeline that can be so emplaced (Pipeline and Gas Journal, 1972).

Location of the crossing must be based on available hydrographic data and erosion rate of the banks, in order to determine length of entrenchment required back from the bank. The crossing should be made at right angles to the streamflow.

For overhead pipeline crossing, bridge-type structures are required. The strength requirements must be individually determined, based not only on the length of the span and the weight of the pipe, but also on local weather conditions that govern wind and ice loadings. Bridge towers must be set well back from the line of the banks of the river or other water body; soil around tower foundations should be selected as safe from erosion. Pilings are also used or a concrete pier foundation is provided to give further protection against erosion or any failure of the supporting soil. Where pipelines designed to carry gas are hydrostatically tested in place (one of several means of testing), the bridge structure must be strong enough to sustain the pipe filled with water (Gas Engineers Handbook, 1969). For bridge crossings, the same pipe dimensions may be used as on the rest of the line. Unsupported spans may be safely used for short crossings such as over creeks and gullies. Care must be taken to ensure that the banks are stable and will provide firm support.

In crossing industrial areas, underground pipelines may require special protection such as insulating flanges against corrosive action; the danger of corrosion may be increased by chemicals that have leaked into the soil and whose presence should be determined by soil sampling. When it is necessary to locate a pipeline aboveground through such areas, it should be placed a foot or more above grade with concrete or masonry piers for support, to which the pipe is held in place by straps.
For pipeline crossings under railroads, roads, streets and highways, regulations of the American Standards Association require a cover of at least 24 inches (Gas Engineers Handbook, 1969). Crossings are typically made by boring or tunneling, although the opencut method is also used. Casings of at least 4 inches greater in diameter than the carrier pipe are frequently employed, but may interfere with cathodic protection of the pipe. Pipes are typically installed at least 3 feet below the lowest point in the ROW crossed.

Transmission Lines

For overhead transmission lines, the most important consideration for water crossings is to ensure adequate clearance of the conductors above the surface of the water as well as over bridges or other construction above the waterline. Allowance must be made for sag under conditions of ice and snow. Clearance requirements are shown in Table V-12. Taller structures are generally required for water crossings. BPA has erected some towers over the Columbia River in the 400 foot range. Where the water can be crossed in a single span, a tall tower is erected on each bank, backed up by a dead end structure to give the conductors more support through rigid attachment than is provided by suspension from the ordinary tangent structures. As previously noted, these structures are from 5 to 10 times as expensive as the lighter suspension towers. When towers must be placed in the water, piling is provided in the bottom, built up out of the water, and capped with concrete. Ordinary tower structures can then by employed.

Requirements for crossing another utility ROW (including highways and railroads) consist largely of maintaining necessary clearances (as shown in Table V-12).

Vegetation Control

For transmission lines, timber cutting--as already indicated in the discussion of clearance requirements affecting ROW dimensions--is of prime importance. Trees not removed during initial clearing may have to be topped or removed as they reach a height that would endanger the line from either conductor swing or falling of the tree itself.

Pipeline ROWs through open land require weed and brush control to a width of 5 to 10 feet on either side of the pipe emplacement. A primary maintenance technique to detect small leaks in the line (insufficient to register as a pressure drop on instrument control panels) is aerial observation of discolored vegetation along the ROW. Thus a uniform ground cover is important. Except in land in agricultural use, seeding and cultivation of cover crops is generally provided as part of restoration after construction and as further needed for erosion control (Gas Engineers Handbook, 1969).

Easements

Typically, the utility acquires the ROW as an easement across property, which establishes the right to construct, operate and maintain the line, and with an easement giving the right of access across intervening property when necessary for maintenance. For transmission lines, this may necessitate a road to provide access to each tower in terrain that is not so mountainous as to require maintenance by helicopter. In any event, helicopter or airplane patrols are made at intervals of from one to six months, supplemented by on-foot inspection at least annually. An important objective is to determine whether structural damage has occurred and whether there has been erosion or other source of weakening to the base of the tower. The access roads may be particularly significant in desert or other thinly vegetated country where both their visual aspect and their potential for impact on the environment considerably exceed that of the line itself.

For pipelines, aerial patrols--which may be conducted as often as weekly--generally provide the basic means of obtaining the information needed for maintenance. On-foot patrol or personal inspection by other means of transportation may also be undertaken at intervals of from 6 to 12 months and as necessary when weather conditions may not permit air flights.

After necessary repair work is completed, the area involved must be restored to its original conditions, with cleanup of debris, soil compaction and restoration of ground cover, just as after original construction. Private owners should be compensated for any damage to property that cannot be fully restored, such as reimbursement for crops destroyed in agricultural land.

Construction Time

Times required for construction of a utility line vary greatly with the terrain and other local conditions. Under favorable conditions, pipeline construction may proceed at average rates of up to three miles per day (Petroleum Extention Service, 1973), although typical rates are considerably slower as shown below in Table VI-16 (Gas Engineers Handbook, 1969).

Transmission lines are normally erected somewhat differently in a sequence beginning with clearance, grading and preparation of access roads at one time, followed by excavation for footing and emplacement of towers. In mountainous country or other regions where heavy weather prevents winter construction, these separate activities may be carried out during the work season (i.e., a continuous portion of the year during which work can go forward) of different years. When there has been extensive preassembly of tower sections, towers can be erected at an average rate of five per day (typically comprising an extent of about one mile). Long lines are frequently installed in sections under contract for simultaneous construction.

The informal estimates based on scheduled construction by the Bonneville Power Administration indicate that a 25-mile line or section can typically be installed in two periods of a few months each. During the first period (which may have to be postponed until the next year because of climatic conditions typically prevailing throughout much of the Northwest), excavation and emplacement is carried out.

Time requirements are seldom significant in assessing alternate routings or determining environmental impacts. The ability to contract to different firms for simultaneous construction enables longer lines to be built at almost any desired rate.

TABLE VI-16

EXPECTED RATE OF PROGRESS IN PIPELINE CONSTRUCTION
(in miles per day)

PIPELINE SIZE, INCHES	LEVEL TO ROLLING TERRAIN		HILLY TERRAIN		LOW WET TERRAIN	
	PROGRESS PER CALENDAR DAY AT 15% LOST TIME	PROGRESS PER WORKING DAY	PROGRESS PER CALENDAR DAY AT 15% LOST TIME	PROGRESS PER WORKING DAY	PROGRESS PER CALENDAR DAY AT 15% LOST TIME	PROGRESS PER WORKING DAY
8	1.57	1.85	1.34	1.57	0.80	0.94
12	1.23	1.45	1.18	1.38	0.69	0.81
16	1.12	1.32	1.06	1.25	0.65	0.76
20	1.0	1.18	0.95	1.11	0.56	0.66
24	0.95	1.12	0.90	1.06	0.53	0.62
30	0.83	0.98	0.80	0.94	0.48	0.56
36	0.81	0.95	0.77	0.91	0.43	0.50

Source: Gas Engineers Handbook, Industrial Press, Inc., New York, 1969

Requirements for Future Growth

Projection of future needs is a complicated operation and a detailed discussion of methodologies is beyond the scope of this report. The utility can be expected to justify the proposed line in terms of meeting existing needs and can reasonably be called upon to estimate future requirements where these are relevant to a consideration of alternative routings. The basis of most predictions of demand is an extrapolation of past trends for a particular utility in the area it serves. Many special factors need to be considered: population growth for the specific region, industrial expansion, and rise of per capita disposable income all normally contribute to increased demand at a rate which can be predicted within reasonable ranges. Conversely, decline in growth factors, if not an actual decrease in utility services, can be expected to diminish the rate at which demand would grow if projected solely from past trends. In the present situation, when availability of fuel is a matter of national concern, the possible impact of systematic fuel conservation measures on future demand can be a complicating factor.*

For the purposes of this report, the important point is that an estimate of growth requirements should be based on a comprehensive set of factors influencing demand. No important considerations should be admitted as to its probable effect, and the estimated results should be consistent with the evidence for all factors.

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*At hearings in Port Gibson, Miss., in February 1974, regarding a proposed nuclear power station, the AEC commissioners raised the issue as to whether the applicant had fully justified the need for additional power. The applicant had utilized traditional methods of prediction based on past growth rates that did not take into account a systematic program for conservation in use of electricity. Although the license was granted, recommendations were made for checking the estimates by the use of additional factors.

APPENDIX

Pipe size and pressure relationships relate the size (diameter) of liquid and gas pipelines to operating pressures

Relationship of Pipe Size and Pressure to Throughput Rate

The throughput rate for liquids in a pipeline is a function of pressure, kinematic viscosity, specific gravity of the liquid (ratio of the weight of the liquid to an equivalent volume of water), and inside diameter of the pipe in inches. The relationship is given by the following formula:

$$P = \frac{Q^{1.748}SV^{0.252}}{156.4D^{4.748}}$$

where P = pressure loss in psi/mile

Q = throughput rate in barrels/day

V = kinematic viscosity in centistokes

S = specific gravity

D = inside diameter of pipe in inches

The relationship may also be expressed in logarithms for convenient plotting on log-log paper, as given below:

$$\log Q = \frac{\log P + \log 156.4 + 4.748 \log D - (\log S + 0.252 \log V)}{1.748}$$

Relationship of Pressure and Pipe Size for Gas Pipelines

The formula used in the Gas Engineer's Handbook (1969) to calculate allowable internal pressure in a pipe is Barlow's formula:

$$P = \frac{2St}{D}$$

where P = design pressure in psig (i.e., psi gauge, the absolute difference of the pressure above one standard atmosphere)*

S = specified minimum yield strength of the pipe in psi as stipulated in purchase specifications and commonly ranges between 24,000 and 52,000 psi

t = nominal wall thickness in inches

D = nominal outside diameter of pipe in inches

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*Thus psia, or psi absolute = psig + 14.7. For very high values, the difference between psia and psig is thus inconsequential.

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SECTION VII
GOVERNMENTAL CONTROLS

SECTION VII

GOVERNMENTAL CONTROLS AFFECTING UTILITY LINES

This section deals with the role of state and Federal laws, regulations, standards and policies in evaluation of utility line proposals.

BACKGROUND

Historically, utilities have long been accustomed to regulatory controls of their lines and corridors exercised at either the Federal or the state level or both.

The present situation of increasing requirements at all governmental levels should be viewed against the background of growing opposition that companies proposing new lines have encountered during the last decade. The period since 1950 has been marked by tremendous growth in facilities for transmitting electric power and for moving pipeline products. For example, the mileage of electric transmission lines increased nearly eightfold from 1950 to 1970, with an expectation of more than doubling again, to more than 159,000 miles by 1990 (Federal Power Commission, 1971). Common carrier petroleum pipelines expanded from about 124,000 miles in 1948 to about 160,000 miles in 1964 and, by 1970, total crude oil and products pipeline mileage of 218,000 miles exceeded the total miles of mainline right-of-way operated by the railroads (Petroleum Extension Service, 1966; Association of Oil Pipelines, 1974).

Whether by chance or through some causal relationship, this increase in demand for transmission and delivery lines and for the land necessary to support them coincided with the tremendous surge in environmental concern. This emphasis on protecting the environment produced the 1969 National Environmental Policy Act (NEPA); NEPA required, among other things, that any Federal action having a "significant" impact on the environment should be preceded by an Environmental Impact Statement. Court decisions have broadened the scope of NEPA as it had initially been interpreted and led to inclusion of additional factors in assessing environmental effects. Further, NEPA served as a stimulus and a focal point for conservation and environmental interests at local and regional levels which resulted in equivalent statutes in some individual states.

The result of increasing restrictions in the form of new laws, regulations and requirements has been to increase the procedural opportunities for influencing location of utility corridors. The approval cycle for construction of new lines has become lengthened. Organized environmental interests working through both regulatory agencies and the courts have been successful in causing the relocation of numerous lines. Preparation and assessment of environmental reports have necessarily become complicated by the additional formal requirements that must be met in terms of increased numbers of permits and authorizations.

REGULATION AT DIFFERENT GOVERNMENT LEVELS

Interstate pipelines for petroleum and other liquid products are regulated by the Federal government through the Interstate Commerce Commission as a result of the Hepburn Act of 1906 extending the earlier Interstate Commerce Act. Pipelines strictly within a single state are usually controlled by an equivalent agency of the state government with some title such as Public Utilities Commission or Corporation Commission. Under the Natural Gas Act, the Federal Power Commission (FPC) is charged with authority for gas pipelines. Safety factors for all interstate pipelines, however, are the responsibility of the U.S. Department of Transportation through its Office of Pipeline Safety.

Regulation of electric transmission lines is largely up to the individual states. There are a few exceptions. The licensing of atomic nuclear generating facilities, formerly under the Atomic Energy Commission, is now the responsibility of the Nuclear Regulatory Commission. Licensing of a nuclear power plant includes approval of a transmission line to connect the generating facility with the transmission grid that it will supply.

The Federal Power Commission has authority under Section 4(c) of the Federal Power Act for licensing of transmission lines that are associated with hydroelectric or pumped storage projects within its jurisdiction. Federal agencies also have responsibility for any utility lines involving the use of any public lands which, in the 11 Western states, comprise about 49 percent of the total area. Additionally, Federal permits may be required under special conditions, as discussed in the next section.

At the state level, regulation typically takes the form of granting a license or other appropriate certification of authority to construct and operate the line.* For specific aspects of a line, special permits may be required of state and local authorities, as discussed in the section on regulations at those levels. Some attempts have been made in particular states to pull together the patchwork of requirements by which utility companies must coordinate with multiple authorities. For the most part, however, regulations and responsibilities remain fragmented.

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*Frequently termed a "Certificate of Public Convenience and Necessity."

As at the Federal level, the trend in the states and localities has been toward increasing regulation, with additional states enacting legislation that requires conformance to land use and other environmental standards and provides authority for state and local instrumentalities to take a more active role in how a proposed line is implemented. The scope of environmental concern seems to be increasingly broadened, not only by legislation, but also by court interpretation. For example, in 1966 the State Water Resources Commission of Connecticut ruled that the 345 kV lines then being constructed over the Connecticut River could remain overhead for only a five-year period. After that period of time, underwater placement of the lines was required. In 1972, the Supreme Court of Connecticut upheld the decision and stated that overhead lines "would adversely affect the beauty of the river." The California Public Utilities Commission ordered the Pacific Gas and Electric Company to relocate segments of 500-kV transmission lines from Diablo Canyon to a "saddle" area. This action was hailed by the Sierra Club as the first time such a Commission had relocated a line on esthetic grounds. Although the North Carolina State Utilities Commission dismissed a complaint on the grounds that it did not have authority to block a transmission line from crossing private property, in Wisconsin the Attorney General won a court decision in a similar case and blocked a utility line from crossing privately owned wetlands.

FEDERAL REQUIREMENTS

Table VII-I lists the Federal agencies, commissions and other organizations with some regulatory authority for transmission lines, pipelines and associated facilities. It is important to ensure that appropriate clearance to proceed has been obtained from these authorities.

Section 7(c) of the Natural Gas Act of 1938 requires a certificate of public convenience and necessity issued by the FPC as a prerequisite to constructing or extending any pipelines for transportation of natural gas in interstate commerce (Federal Power Commission, 1974). The FPC, in deciding to authorize a pipeline, takes into account the probably environmental effects, specifically in terms of scenic, historic, recreational and wildlife impacts (18 CFR 2.69, 1972). The

TABLE VII-1

SOURCES OF FEDERAL RESPONSIBILITY IN REGARD TO UTILITY LINES

- U.S. Forest Service Agriculture Department
- Council on Environmental Quality
- Defense Department
  - U.S. Army Corps of Engineers
- Environmental Protection Agency
- Federal Communications Commission
- Federal Power Commission
- Interior Department
  - Bureau of Indian Affairs
  - Bureau of Land Management
  - Bureau of Reclamation
  - Fish and Wildlife Service
  - National Park Service
- Transportation Department
  - Coast Guard
  - Federal Aviation Administration
  - Federal Highway Administration

Commission's guidelines include the following objectives:

- Minimum soil erosion (including concern for construction of access roads)
- Minimum damage to
  - Shorelines
  - Recreational areas
  - Aquatic biota
  - Wildlife habitat
- Reestablishment of marshes, wetlands, etc.
- Stabilization of temporary roadbeds after abandonment
- Prevention of soil or water pollution from defoliants used in maintaining ROW
- Care during pipeline testing in water to ensure that harm does not occur to terrestrial or aquatic biota and that there is no degradation of water quality

In practice, much of the Federal regulation of utility lines is exercised through the NEPA requirement of an Environmental Impact Statement regarding any major Federal action that will significantly affect the environment. This is particularly true of transmission lines associated with nuclear generating facilities, the consequences of which are assessed in the Nuclear Regulatory Commission's environmental evaluation. Under the guidelines promulgated by the Council of Environmental Quality (CEQ) pursuant to NEPA, an environmental impact statement (EIS) must analyze both the costs and benefits of the proposed action on the overall environment. Specifically included are impacts on ecology, land use and development patterns, and the socioeconomic structure. Possible alternatives must be assessed; other locations for the utility line are particularly significant.

Environmental Impact Statements are required by the Department of the Interior (including, specifically, the Bureau of Land Management and Bureau of Reclamation) in connection with the issuance of any permits, licenses, or other entitlements of use such as would be required for lines crossing public lands managed by Bureaus of DOI.

Permits are required from appropriate Federal agencies and departments for transmission lines, pipelines, and associated facilities under the following conditions:

a. Aviation Obstruction

The Federal Aviation Administration (FAA) requirements are contained in "Advisory Circular on Obstruction Marking and Lighting." Permits are necessary for any structure over 200 feet tall located close to designated airports.

b. Crossings of Navigable Rivers

The U.S. Army Corps of Engineers requires a permit for a transmission line, pipeline or communication line that crosses navigable waters or their tributaries. Before acting on application for a permit, the Corps requires comments from the following agencies:

- U.S. Fish and Wildlife Service (DOI)
- State Department of Natural Resources (or equivalent)
- State Pollution Control Agency (or equivalent).

Section 10 of the River and Harbor Act of March 3, 1899 (33 U.S.C. 403) requires permits for power transmission lines crossing navigable waters of the United States. However, when such lines are part of a water power project subject to the regulatory authorities of the Federal Power Commission (FPC) under the Federal Water Power Act of 1920 (16 U.S.C. 797), application is made to the FPC.

Regulations prescribe minimum clearances required for electric power transmission lines crossing navigable waters of the United States. The clearances specified refer to the low point of the line under conditions of maximum sag calculated for temperature, load, wind, length of span, and type of supports as outlined in the National Electrical Safety Code. The following clearances are set relative to the clearances over the navigable channel provided by existing fixed bridges, or the clearances that would be required by the U.S. Coast Guard for new fixed bridges.

Nominal System Voltage, kV	Minimum Additional Clearance (ft.) Above Clearance Required for Bridges
115 and below	20
138	22
161	24
230	26
350	30
500	35
700	42
750-765	45

c. Crossings of Bays, Inlets, or Harbors

The U.S. Coast Guard requires a permit.

d. Crossings of Department of Agriculture Lands

The U.S. Department of Agriculture requires a permit issued by the relevant National Forest.

e. Location within Right-of-Way of Interstate Highway Facilities

Approval must be obtained from the Federal Highway Administration. Currently, however, this Administration has a general policy against such use of its ROW.

STATE REGULATIONS

Much variety exists in regard to regulation and procedures governing utility lines applied in the different states. Some assert no jurisdiction in regard to location. Approximately two-thirds of the states require approval of some aspect of utility corridors and transmission lines. A 1972 survey source revealed that in 15 states all transmission lines must be licensed. An additional 17 states have more limited licensing requirements. Other states have passed or have pending environmental legislation modeled after NEPA.

In addition to the specific licensing of transmission lines, many state and local permits are required to build an interconnection with an existing line. Special permits are typically required for a line involving specific areas or existing facilities, such as locations on state lands, any use of significant waterways as defined by state law, or crossing or sharing the ROW of a state highway. Local zoning ordinances (particularly those applicable to land use and the crossing of roads and other public property) have a major effect on siting of new transmission lines. The licensing process is more complex, however, since instead of dealing with one or two municipalities (as for a generating facility) the utility must seek permits from all the local jurisdictions along the line's route. State agencies most commonly involved in regulation are those responsible for:

- Conservation
- Environment
- Fish, Game, and Wildlife
- Forestry and Agriculture
- Highways
- Lands
- Recreation, Parks, etc.
- Regulation of Utilities (Public Utilities Commission, Public Service Commission, State Corporation Commission, etc.)
- Rivers and Other Waterways
- Special Authority for Siting
- Water Quality

Authorities at the city and county level may also require coordination to ensure compliance with regulations applicable to utility lines in line with their designated responsibilities for:

- Boards of Architectural Review
- City Council
- Conservation and Development Commission(s)
- County Board of Supervisors

- County Road Department(s)
- Fire Department(s)
- Flood Control Districts
- Planning Commission(s)
- Sanitation Districts
- Zoning Board(s)

Arizona

Arizona has a state Power Plant and Transmission Siting Regulation that established a siting committee to pass on proposed transmission lines and power plants. An application for a certificate of environmental compatibility must be filed by a utility planning to construct a transmission line. This application must be accompanied by an environmental report. In determining whether to approve the application, the committee gives special weight to the protection of sensitive biologic areas. Other factors include compatibility with existing plans for the region; noise and interference with communication signals; possible multiple use for public recreation; scenic, historic and archeologic areas; and "the total environment of the area." Technical practicability and cost are also considered. Power companies are also required to file a 10-year plan with respect to proposed facilities (State of Arizona, 1971).

There is also a common carrier law by which pipelines that are recognized as common carriers must be registered with the Arizona Corporation Commission. Utility lines are also affected by the state policy on land use. Although, at present, there is no legislation establishing a comprehensive land use plan, the Arizona Environmental Planning Commission has prepared guidelines. However, those guidelines have not as yet been approved by the legislature. When State Trust lands are involved, a utility corridor or ROW must be evaluated as to its merits before authorization can be granted. Under the Urban Environment Management Act of 1973, new planning and zoning regulations were established for cities and towns.

California

California was one of the first states in the Union to pass an environmental act similar to NEPA. Chapter 3 of the California Environmental Quality Act (CEQA) of 1970 provides for provisions almost identical to those of NEPA:

> "All state agencies, boards, and commissions shall include in any report on any project they propose to carry out which could have a significant effect on the environment of the state, a detailed statement by the responsible state official setting forth the following:
>
> (a) The environmental impact of the proposed action.
>
> (b) Any adverse environmental effects which cannot be avoided if the proposal is implemented.
>
> (c) Mitigation measures proposed to minimize the impact.
>
> (d) Alternatives to the proposed action.
>
> (e) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity.
>
> (f) Any irreversible environmental changes which would be involved in the proposed action should it be implemented."

The explicit requirement to specify mitigation measures (Section c) of CEQA is an important distinction between it and NEPA. The CEQA contains the provision that the growth-inducing impact of the proposed action should be specified.

General Order 131 issued by the California Public Utilities Commission requires that, for all transmission lines of 230 kV or greater, application be made with the Public Utilities Commission for a Certificate of Public Convenience and Necessity. An environmental report must be submitted by the applicant; this becomes an important input to the decision-making operation by the Public Utilities Commission. A similar procedure is followed in regard to pipelines.

Under CEQA, the responsibility for administering the state environmental impact statement is assigned to the Office of Planning and Research (OPR). OPR has responsibilities to establish guidelines, criteria and procedures for both preparation and evaluation of impact statements. A limitation on the potential effectiveness of CEQA is the absence of any clearly delineated authority to ensure that after review of an impact statement a proposal would be modified to eliminate or reduce potential impacts deemed significantly adverse. The absence of a state office analogous to the Federal CEQ has been noted in an EPA study of the California Environmental Quality Act (U.S. Environmental Protection Agency,1974).

Utility lines may also be affected under California legislation affecting land use. In particular, the California Coastal Zone Conservation Commission Act of 1972 requires the statewide Coastal Zone Conservation Commission and six regional commissions to prepare by 1976 a comprehensive plan for managing the defined strip along the Pacific Coast. Any activity 1000 yards inland from the mean high tide line requires a permit from the appropriate region.

The Warren Energy Act, AB 1575, enacted in May 1974, specifies in regard to siting of power plants and related facilities that the Public Utilities Commision has "the exclusive power to certify all sites and related facilities...No construction of any facility or modification of any existing facility shall be commenced without first obtaining certification...." The Act further stipulates that "each person proposing to construct a thermal power plant or electric transmission line on a site shall submit to the commission notice of intention to file an application for the certification of such site and related facility or facilities" and that "no construction of any thermal power plants or electric transmission line shall be commenced by any electric utility without first obtaining certification as prescribed...." (State of California, 1974). This Act also gives the state authority to override local rules and regulations.

Colorado

In Colorado, an electric power or a natural gas company planning an intra-state line may be required to apply for a Certificate of Public Convenience and Necessity from the Public Utilities Commission (PUC) if the proposed line constitutes an extension of service by the utility. This Commission has authority to grant or withhold the Certificate after one or more hearings stressing the needs of the customers for the new service to be provided by the additional line. The utility has submitted system maps to the Colorado Land Use Commission (CLUC) for record and mapping purposes, but is not required to submit new utility line plans to the CLUC for their comments at this time. The state law provides that other licenses and franchises must be acquired by the applicant utility in order to proceed, and these sometimes include permits from the counties and other localities affected.

No application for a slurry pipeline has arisen and it is not definite as to what the procedure will be. It is anticipated that a common carrier slurry line would be subject to regulation by the PUC, but a single-company line would have no more restrictions than oil pipelines do at present.

There are state regulations in Colorado relating primarily to duplication of electric transmission facilities and sharing ROWs. The Public Utilities Commission can require one electric power company to transmit or "wheel" the power of another in order to avoid duplication of facilities. As a result, locations of lines can be affected. An authorized service area, where one power company has exclusive rights to provide customer service, does not block another line from passing through.

There is no policy dealing with establishment of general corridors for natural gas, crude oil, or products pipelines.

As an inducement to shared use of a ROW, the Colorado State Land Board adjusts rentals to offer a reduced rate when another facility uses an existing ROW. As an example, three transmission lines from different companies were recently induced by the Land Board to use the same corridor on open plains country near Pueblo and Colorado Springs. No conflicts are known to exist between practices of established utility corridors and policies of the Land Board. As a quantitative standard, the Land Board generally sets 70 to 100 feet as ROW width for electric transmission lines using H-frame construction.

It is the policy of the Colorado Division of Highways to permit telephone lines as well as underground or overhead electric transmission circuits to occupy land within or adjacent to the ROW of state highways. Pipelines cross highways as necessary.

An important action relative to the role of local governments was the passage on May 17, 1974, of the Local Government Land Use Control Enabling Act and the Areas of Activities of State Interest Act. These laws extend the authority for local governments to become involved in the regulation of utility and transportation corridors. However, the practical effect of these laws is not yet known, either in regard to how active the local governments will be or as to what action may be taken at state level if the localities are not regarded as sufficiently forceful.

Idaho

Idaho has no land use policy nor any specific law governing power plant or other utility siting. However, the Public Utilities Commission approves permits for proposed lines on an individual basis. Cities and counties exercise control over location of utility lines through their authority to plan and zone land under their jurisdiction.

Montana

In 1971, Montana passed the Montana Environmental Policy Act (MEPA), modeled after NEPA, and provided for a state council similar to CEQ. The Montana Council is an advisory body without enforcement authority. The real power is exercised by the Department of Natural Resources which, under the Utility Siting Act of 1973, has the power to grant or withhold a permit for any electric generating plant and for transmission lines associated with it. The 1975 legislative amendments to the Utility Siting Act provide that its provisions apply to each electric transmission line of a design capacity of more than 69 kilovolts except that such lines of 230 kilovolts or less and less than ten miles in length are excluded from the Act.

These 1975 amendments also provide that the Act is applicable to gas, water or liquid hydrocarbon pipelines to or from certain large electric generating, gasification, liquefaction, petroleum, and nuclear facilities. Only applications received by the Department of Natural Resources are covered by these amendments.

There is no present provision for establishing joint-use corridors in the state which would be required for future use by utilities. Current belief is that there are too many variables and unknown factors to provide in advance for comprehensive needs and that proper flexibility is maintained by considering each need as it arises.

Municipalities exercise control through their zoning laws. Counties also have authority to enact zoning ordinances, but under state law these can be blocked by action of the property owners. The state frequently imposes regulations as it is authorized to do under state law when local governments fail to act.

Nevada

Nevada has a State Land Use Planning Act (SLUPA), passed in 1973, and a Utility Environment Protection Act (UEPA) of 1971, amended in 1973. Under SLUPA, a land use planning program will be developed in fiscal years 1975-77 that will identify critical environmental areas requiring environmental impact statements. The Department of Conservation and Natural Resources will administer the Act. Pending completion of this program, however, there is no overall state land use policy.

UEPA requires the Public Service Commission to approve siting of facilities proposed by utility companies. The State Planning Project Coordinator also has responsibilities in this regard. He evaluates competing demands for resource allocation and program accomplishment and serves to provide an information clearinghouse for implementation of planning and project reviews.

In Nevada, an important role in regard to specific localities is filled by the Colorado River Commission, which is primarily concerned with utility corridors in the Fort Mohave Valley and the Eldorado Valley Development Areas.

State legislation provides for local governments to establish zoning and associated regulatory controls for land use, which includes control of types of utility corridors and location of lines.

New Mexico

The state's Environmental Quality Act of 1972 was repealed by the legislature in 1974. Transmission lines of voltage equal to or greater than 230 kV are regulated by the Public Service Commission, which has authority to oversee the environmental compatibility of such lines through issuance of a Certificate of Public Convenience and Necessity. An environmental report is required from the applicant utility company. This is reviewed by, among others, the Environmental Protection Agency. A permit is also required from the State Office of Land Development.

On intrastate pipelines, there are no state restrictions. The state Oil Pipeline Commission has jurisdiction only in regard to pipeline spills that endanger water. State permits or certification are not required for pipeline construction.

Local authority is weak in New Mexico. The state law allows cities with populations of 25,000 or more to have executive planning jurisdiction. But there is no extraterritorial zoning jurisdiction exercised by municipalities, nor do the counties have any significant land use authority.

The state has no official policy regarding general corridors for utility lines. However, the use of shared and multiuse ROWs is encouraged in several ways. In January 1971, the New Mexico Highway Commission promulgated a manual entitled "Regulations, Policy and Procedures Governing Occupancy of State Highway System Right-of-Way by Public Utility Facilities." The objectives were to maximize public use of ROWs under state law, by which a public utility has a right to install its facilities within a highway ROW subject to regulations of the State Highway Department. The courts in New Mexico have held that public utility facilities are not ROW encroachments and may not be treated as such.

A task force has been established to assist the Division of Natural Resources in the State Planning Office to complete a report entitled "New Mexico Energy Corridor Study." This report attempts to define the pattern that should be taken by utility corridors, particularly in light of future population growth and national energy demands. Recommendations made in the report include maximum use of existing corridors; establishment of such compatible multiple uses as recreation bikeways, equestrian trails, and hiking paths within utility corridors; and use of existing highway corridors, especially in heavily forested areas.

It is interesting to note that the Navajo Tribe has studied the establishment of utility corridors across its reservation. The tribe's Office of Program Development issued a report that includes a schematic drawing of a "typical proposed utilization of utility corridor." This corridor provided for an existing 345 kV line, a proposed 500 kV line, and an existing gas line, as well as proposed service roads, railroad, and additional gas pipelines. The corridor was indicated as 1000 feet wide, nearly 300 feet of which would be left open for future ROW uses.

Oregon

A comprehensive land use bill (SB 100) was passed by the legislature and signed into law in 1973. Statewide efforts to implement it are in progress. Specified primary areas of environmental concern include those adjacent to highway interchanges, estuarine regions and floodplains. Regulation of utility lines in these areas is based on licensing procedures as a public utility service, with a permit required from the Land Conservation and Development Commission. Approval is required from the Highway Department for any use of its

ROW, either for crossing or sharing. However, neither the Public Utilities Commission nor any other agency exercises general control over location and establishment of utility lines at the state level.

Utah

In Utah a proposed State Land Use Plan failed to be ratified by the voters in 1974. Under an executive order recently issued by the Governor, state agencies are required to file environmental impact statements for actions taken. However, no state agency has a designated responsibility for determining the location of utility lines. Local control comes through county governments, with utilities required to obtain authorization from the three-man commission that comprises the executive authority in each county.

Washington

A state environmental policy act of 1971 closely parallels NEPA. The Department of Ecology received broad powers to establish guidelines and criteria for preparation of impact statements. Although there is no statewide land use policy at present, the Shoreline Management Act of 1972 provides for regulation of land extending 300 feet from the high water mark along the shore, as well as land associated with large lakes and moving bodies of water.

A Thermal Power Plant Siting Act of 1970 regulates the siting of power plants and associated transmission lines. Otherwise, utility lines do not require general authorization or approval of proposed location at the state level.

Wyoming

Wyoming exercises regulation over utility line locations and their potential environmental impacts---principally through the recently passed state land use planning act and plant siting bills. Utility lines are also controlled through requirements for a license issued by the Public Service Commission. In the state, 18 of the 23 counties currently have planning commissions.

The State Land Use Planning Act passed in 1975 created a commission empowered to designate critical areas where development might damage the environment. These include fragile or historic lands, natural hazard lands, renewable resource lands, and new town lands. Land use definitions and a state land use plan are to be developed under the terms of this Act, which also directs local governments to develop land use plans for areas under their jurisdiction (State of Wyoming, 1975a).

The Industrial Development Information and Siting Act requires a permit from the Industrial Siting Council for construction of energy generating and conversion plants and additions thereto (including, specifically, power plants generating 100 megawatts of electricity), as well as of any industrial facility costing at least $50 million (an amount subject to annual adjustment by the council). Assessment of the environmental impact of the proposed project is required, as well as its compatibility with any existing state and local land use plans. Pipelines and electric transmission lines not exceeding 115 kV are specifically exempted from the application and permit procedures of the act. However, in connection with these facilities,information describing the facility, its construction time, and estimated distribution of employees must be furnished (State of Wyoming, 1975b).

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SECTION VIII
SHARED AND MULTIPLE USE

SECTION VIII

SHARED AND MULTIPLE USE

OVERVIEW

Two concepts developed to provide for potentially better use of the areas devoted to utility rights-of-way are those of shared and multiple use. Shared use refers to the use of the same corridor by two different utility rights-of-way serving distinct purposes such as highway, transmission line, pipeline, etc. Multiple use refers to utilization of a utility right-of-way for various recreational or commercial purposes as well as for utility lines.

SHARED USE

Shared use means increasing the utilization of a single right-of-way in order to accommodate one or more additional utilities so that the resultant amount of land used and the attendant impacts are less than those which would occur if separate ROWs were provided. These goals may also be accomplished by sharing the areas needed for construction and maintenance of the utility lines.

General Considerations

There are numerous examples of "systems" or "networks" of utilities which share a common ROW. Most of these are not the result of a conscious effort by all users to achieve a shared use concept but instead are simply a collection of point-to-point operations whose location has been dictated by geologic, geographic and demographic conditions. They have developed over a period of many years. Natural opportunities for shared use of rights-of-way exist in some situations, and such usage is desirable where its benefit is clearly greater than its cost.

Many factors affect both the feasibility and the desirability of shared use ROWs. For instance, the economics of a given situation must be considered as well as the environmental factors. In this regard, the timing of installations is an important consideration in examining the feasibility of a shared use ROW. Market demand for the various uses will dictate the timing of installation under the shared ROW concept. Capital investment and the cost of capital for each potential user's facility is a constraint to simultaneous installation of all facilities unless there is a reasonable rate of return of the investment. Facilities should not be installed and left idle or substantially underutilized. Again, each type of facility is highly capital intensive, difficult to finance and, in each, the largest single cost of operation is the cost of capital. These costs begin before construction or operation begins. Consideration of all potential uses in a shared corridor at the time of an application by a single potential user may substantially delay the single potential user's project. This delay would translate directly into increased costs.

There are also constraints in that the ownership and operation of potential joint use ROW facilities is generally vested in differently organized industries or agencies. For the most part, the development of one type of operation by the owner of another is prohibited. (In some areas, utilities that provide both gas and electric service are the exceptions.)

The Electric Utility Task Force of the Intersystems Coordination Group (U.S. Department of the Interior, Bureau of Land Management, 1974), after studying existing shared use of utilities, reports the following advantages and disadvantages of shared use development where feasible:

Possible Advantages of Shared Use

a. minimization of total land use in the area of the corridor

b. minimization of land costs within the corridor

c. minimization of need for access roads because of common use

d. maximization of open space for recreation purposes

e. minimization of land subject to adverse visual impact

f. reduction of lead time required to reach mutual agreement with Federal agencies on route selection

g. simplification of environmental reporting

Potential Disadvantages

a. in the event of industrial and other man-made activities, which would include war, the exposure is increased; this situation extends to natural causes as well

b. after any disastrous event, restoration of services would be complicated by the presence of other utilities

c. adverse esthetic and environmental impacts are magnified on a local scale

d. private land costs may be increased due to lack of alternatives in route selection where the Federal land corridor abuts private land

e. route planning flexibility is reduced

f. the potential for unsafe working conditions in operation and maintenance is increased

g. if corridors were selected based on existing routes, in some instances, the addition of more facilities could over-impact certain areas in esthetic and other considerations

h. policy of scenic highway designations may be adversely impacted

i. circuitous routing could impose major economic penalties in both construction and land costs and may also require utilization of excessive amounts of public and private land

j. forcing transmission lines to follow curvature of routing of adjacent facilities would add significantly to design and construction cost and to the use of construction materials

When considering the shared corridor concept, it would be desirable to determine the possibilities for shared use while in the planning stages. It may be difficult to enlarge a single ROW to accommodate an additional utility after the first is in operation. Although the addition of a utility line in an existing utility ROW may be feasible, in the ideal situation, simultaneous construction of all utilities within the ROW would occur with no disruption of service. Since, at the present time, there are few regional planning boards coordinating the development of all utilities, efforts should be made to investigate the plans of as many local utility companies as possible, including those of electric power, communications, pipelines, railroads and highways.

Adequate planning and consultation with prospective corridor neighbors should be conducted early in the siting study in order to identify any possible adverse interactions between the systems and to devise an equitable method for solving them. For example, the shielding required to protect other utilities such as railroads, communications systems, and pipelines, from interference by high-voltage transmission lines is generally quite expensive and there is some debate as to whether the electric utility should pay the whole cost or whether the combined corridor users should divide it. Typically, when an overhead transmission line seeks to locate in or adjacent to a ROW occupied by another utility, the electric company is expected to pay for all precautionary measures required. In planning for future shared-use corridors, the possibility of some less one-sided arrangement may need to be explored.

Technical considerations for shared use development include design, installation, and operational requirements of each utility in a given right-of-way. Design specifics, including utility loading capacity, quality of construction, preventive maintenance procedures, soil characteristics, topography, and environmental conditions are among the factors creating disparities when comparing two otherwise similar examples of shared use development. These design criteria may explain, for example, why 10 miles of parallel 345-kV lines and a coaxial communication cable with a 500- to 5000-foot separation in one instance required no mitigation, while in another instance shared development for the same distance and involving the same power voltage with a coaxial communication cable and a 3500- to 6200-foot separation necessitated the use of steel pipe to shield the cable (Aerospace 1975). Because of variations in design criteria, it may not be practical to establish a fixed set of guidelines applicable to all incidences of shared use. Certain generalities, however, may be useful in determining feasibility of shared use development.

In determining the feasibility of shared use development, three interrelated considerations are:

a. Dimension requirements

b. Safety and reliability

c. Esthetics

Dimension Requirements

Design constraints such as topography and type of soil, as mentioned above, are responsible for the great deal of disagreement existing among utility companies in determining minimum ROW widths and separation between utilities. For instance, as evidenced in the report by Aerospace Corporation (1975), some utility companies have stated that 3 to 5 feet between pipelines is sufficient, while other companies prescribe a minimum of up to several hundred feet.

Width constraints may limit the possibilities for two or more non-overlapping ROWs immediately adjacent to one another in a single corridor. Where there is sufficient space available alongside an existing line for significant portions of its length, it is possible to plan a second line to run parallel, with each utility having its own ROW. In some situations, however, this practice may be precluded by natural obstacles and/or by constraints on land use.

The fact that some utility lines run underground, whereas others are on the surface or overhead, makes it tempting to consider economy of land use by means of overlapping ROWs. For example, the 100 feet required to emplace a 48-inch pipeline might be part of the 185-foot width of a 345-kV single-circuit transmission ROW. Or a transmission line might run alongside a highway or railroad. While the dimensional requirements could be met in this way, other problems exist. It is necessary to ensure that heavy equipment used for construction of a second utility line does not operate on top of an emplaced pipeline--a practice that is carefully avoided in constructing a second pipeline adjacent to one that already exists. Where the ROW is already occupied by a surface line such as a highway or railroad, the cost and engineering difficulties of tunneling to lay a pipe beneath the transportation route may make it infeasible to do so for long stretches.

Differences in grade requirements for various utilities may, upon occasion, make certain potential shared use development infeasible. Both railroads and highways, for instance, have restrictions on the maximum grade they can traverse. In mountainous terrain, interstate highways are limited to 7 percent slope, while railroads are generally restricted to no more than 2 percent. Table VIII-1 gives general dimension and slope requirements for utility ROWs. These requirements necessitate a rather circuitous route through rugged terrain. Pipelines and power lines, on the other hand, are relatively free of slope restrictions on technical grounds, with the exception of the maximum grade of 16 percent acceptable for slurry pipelines. These utilities are thus limited largely by environmental constraints, such as the higher erosion potential of steep slopes. Even in rugged terrain, they can seek the obvious advantages of a straighter route rather than the more circuitous route imposed on a transportation ROW by grade limitations.

Technical difficulties in establishing compatibility between two or more utility lines is highly correlated to size of the ROW and the subsequent space allowed between utilities. Generally, a narrow shared use corridor will inhibit the potential for the future inclusion of additional utilities, or would require a great deal of mitigation and some coordination of construction activities. On the other hand, a very wide corridor may require no special mitigating efforts to establish utility compatibility. Transmission lines may require the greatest separation distance from other utilities in order to prevent fault currents or electric induction. Pipeline ROW requirements, however, are established primarily by the material and size of equipment involved in the operations. ROW width requirements may thus be increased if the slope is steep or if the pipeline is crossing rivers or intersecting other systems because space for additional equipment and working area may be necessary for construction and maintenance.

Safety and Reliability

Shared use of ROWs and the resultant safety and reliability of utility systems involved is one of the prime considerations in determining the practicality of shared use development. Reliability of a utility system may be based on the stability of system design and the ability to handle abnormal occurrences, with the need for safety (both for humans and for the environment) increasing the need for reliability.

TABLE VIII-1

RIGHT-OF-WAY DIMENSION REQUIREMENTS

UTILITY	DIMENSION*
Pipelines	Normal terrain, ROW construction width approximately 50' for single 10-12" pipe to 100' for 48" pipe. Operating widths 10'-20' to 40'-50' maximum. Slope limitation 16% for slurry lines.
Electrical Transmission	Width may be as narrow as 60'-70' (with some wood poles, as narrow as 50'). Slope up to 100% may be traversed.
Railroads	Maximum allowable grade in prairie conditions 1-1.5%, mountains, 2.2%.
Communications	ROW construction width varies from 25-30' to 100', operational widths from 16'-50'. Additional width required at repeater or terminal stations.
Highways	ROW width for four-lane, divided, priority primary route class 90'-300'.

*Data assuming single utility with corridor unoccupied by other systems.

Sources: Aerospace Corporation, Technical Compatibility Factors for Joint-Use Rights-of-Way, for the Bureau of Land Management, U.S. Department of the Interior, February 1975.

Energy Transportation Systems, Inc., Facts Concerning Proposed Coal Slurry Pipeline From Wyoming to Arkansas, San Francisco, Calif., March 1974.

Shared ROW use increases the potential for a single incident to disrupt service of more than one utility line. This can create a critical situation if alternative utility routes do not exist. Thus shared corridors may be preferential targets in case of sabotage or war, with the possibility existing that whole cities may be isolated by strategic attack.

Reliability and safety considerations may be more crucial for assuring uninterrupted service of electricity than of other utilities. The disruption of transportation, for instance, may require rerouting and additional cost or inconvenience, but the disruption of normal service would not necessarily be catastrophic. Similarly, pipeline gas and oil systems generally have stored reserves at primary destination points. On the other hand, electricity is generally not stored. The loss of primary electrical power could thus create significant problems for industrial users and the public. The recent power line and substation bombings in the Pacific Northwest and California have shown the wisdom in providing redundant systems.

The most serious problems in regard to placing a power transmission line adjacent to other utilities arise because of safety and reliability considerations. As already noted in the subsections discussing these factors, induction and the existence of currents from line faults or lightning strikes may pose a hazard to personnel and to flammable materials flowing in a pipeline. Interference from high-voltage lines may disrupt operation of cathodic protection systems, of electronic circuitry and of communications systems required by other utilities. To avoid such problems, utilities have generally relied upon wide separation of transmission lines by distances that range from 1000 feet up to as much as one mile. Costly shielding and other protective measures, such as special grounding and filtering to reduce harmonics, are required where a transmission line is located in close proximity to another utility (Aerospace, 1975). In each situation where shared use of a corridor is considered, the efficiency in actually providing the necessary degree of protection as well as the associated cost must be carefully weighed against the estimated benefits of reduced land use and avoidance of potential environmental impacts in an alternate location.

Because of the influence that utilities have on each other, it may be ill-advised to locate different utilities as close together as construction practices will allow. Tables VIII-2 and VIII-3 show some of the interactions that may occur between the various utilities necessitating a degree of separation for the purpose of safety and continuing reliability. The utility systems that cause by far the greatest amount of difficulty are electric transmission systems. High voltage electrical systems create powerful electromagnetic fields that can cause interference with any other electric system in its area of influence. These effects become pronounced as the distance over which

TABLE VIII-2

INTERACTION OF ELECTRICAL TRANSMISSION LINE IN SHARED RIGHT-OF-WAY

	OTHER ELECTRICAL TRANSMISSION LINES	COMMUNICATIONS	PIPELINES	RAILROADS	HIGHWAYS
Effects of electrical transmission line on other utility line	Problems Reliability degraded. Safety during maintenance from voltage gradient.	Problems Steady state noise. Fault and lightning damage. Shock hazard. Corrosion of cable sheath. Construction damage. Communications interference.	Problems Corrosion. Shock hazard. Fire/explosion hazard. Pipeline rupture. Damage to pipeline during construction and maintenance.	Problems Shock hazard. False control signals. Communications interference.	Problems Radio noise. Audible noise. Esthetic impact. Interruption of vehicular flow during construction and maintenance
	Mitigation Increase separation. Shielding.	Mitigation Increase separation. Shielding. Lightning arrestor or spark-gap protection for faults and lightning. Filter electric lines to reduce harmonics. Increase conductor size, bundling, insulation.	Mitigation Increase separation. Shielding. Cathodic protection. Low conductivity coating on pipe. Ground pipe while welding, at substations, and at test points. Avoid construction over pipeline location.	Mitigation Increase separation. Shielding. Filtering electric lines to reduce harmonics. Use pulse-code communications. Avoid open-wire or ground-return communication circuitry.	Mitigation Increase separation. Shielding. Screen to reduce visual effect.
Effects of other utility line on electrical transmission	(See Above)	Problems Construction damage.	Problems Fire/explosion hazard. Construction or maintenance damage.	Problems Derailment caused outage; reliability degraded. Fault currents transmitted by rails may be hazard to transmission line maintenance personnel.	Problems Transmission reliability degraded due to accident-related outages. Traffic endangers transmission line maintenance personnel.
		Mitigation Increase separation	Mitigation Increase separation.	Mitigation Over-voltage protection for tracks to prevent fault transmittal problems and spark-gap protection for transmission lines.	Mitigation Increase separation.

Source: Aerospace Corporation, Technical Compatibility Factors For Joint-Use Rights-Of-Way, for the Bureau of Land Management, U.S. Department of the Interior, February 1975.

TABLE VIII-3

INTERACTION OF PIPELINE IN SHARED RIGHT-OF-WAY

	ELECTRICAL TRANSMISSION	COMMUNICATIONS	OTHER PIPELINES	RAILROADS	HIGHWAYS
Effects of pipeline on other utility lines	Problems Fire/explosion hazard. Construction or maintenance damage.	Problems Cathodic protection interaction. Fuel leak damage/personnel safety. Construction damage.	Problems Cathodic protection interaction. Fuel leak/fire and explosion hazard.	Problems Construction damage. Fire/explosion hazard.	Problems Interruption of vehicular flow during construction and maintenance. Fire/explosion safety hazard.
	Mitigation Increase separation.	Mitigation Increase separation. Cathodic shielding.	Mitigation Increase separation. Cathodic shielding.	Mitigation Increase separation.	Mitigation Increase separation.
Effects of other utility line on pipeline	Problems Corrosion. Shock hazard. Fire/explosion hazard. Construction or maintenance damage. Pipeline rupture.	Problems Construction damage. Pipeline ruptures.	(See Above)	Problems Derailment damage to valves, compressor or pumping stations, etc. Pipeline rupture.	Problems Access interference. Fire/explosion safety hazard. Vehicle damage to above-ground facilities due to accident. Pipeline ruptures. Traffic endangers pipeline maintenance personnel.
	Mitigation Increase separation. Shielding. Cathodic protection. Low conductivity coating on pipe. Ground pipe while welding, at substations, and at test points. Avoid construction over pipeline location.	Mitigation Increase separation Avoid construction over pipelines.		Mitigation Increase separation. Avoid construction over pipeline location.	Mitigation Increase separation. Avoid construction over pipeline.

Source: Aerospace Corporation, Technical Compatibility Factors For Joint-Use Rights-Of-Way, for the Bureau of Land Management, U.S. Department of the Interior, February 1975.

paralleling occurs is increased. In addition, hazards due to faults in the line caused by lightning or accidental grounding can seriously disrupt any nearby systems. Construction hazards are increased if an electric transmission line is installed prior to other systems. It may be advisable to schedule other construction work when regular maintenance and testing of power lines is taking place in order to avoid electrical surges. In most instances of shared development not involving transmission lines, the utilities may more easily be made compatible with each other, with proximity limited largely by construction accessibility and maintenance requirements.

Esthetics

In regard to esthetic impact, some controversy exists over shared utility corridors. Many observers feel the effects of two or more utilities side by side are not as great as the combined effects of the separate utilities. On the other hand, the additional widths needed to maintain adequate separation between several separate utility systems can necessitate corridors up to one-half mile or more in width. Such extremely wide corridors produce a much greater visual impact than the ROW of an individual system. Southern California Edison has noted that more than five transmission lines parallel to each other produce an esthetic effect sufficiently adverse that the company seeks to avoid them. It has already been noted that one of the strong objections to overhead power lines paralleling a highway is largely based on the extent of visual impact to which motorists are exposed. Whether the visual incompatibility of a single wide corridor containing several utility lines is greater than the sum of the impacts of separate ROWs is a very difficult matter to assess and depends to some degree on local conditions. For example, a very wide break in a wilderness area or scenic region might well be more objectionable than narrower ROWs with towers and other structures screened by trees and blended with the topography. In this respect, the esthetic suitability of shared use corridors relates highly to land use, esthetic placement and treatment of ROWs and local attitudes.

MULTIPLE USE

Multiple use of a ROW involves participation by individual citizens, a community, or commercial groups in one or more activities that do not detract from operation and maintenance of the utility line. The choice of compatible uses depends on maintaining both public safety and reliability of the utility line, as well as on the ability to minimize disruption of the surrounding land use.

Through multiple-use development of utility ROWs, the public need for open space, recreation space, or community facilities may be at least partially satisfied. Multiple-use development is beneficial in several ways.

Benefits to the Community

a. maximization of open space for recreation and community use

b. provision of needed community facilities

c. reduction of esthetic impact of the ROW

d. physical integration and connection of neighborhoods, parkland, and other facilities

e. separation of pedestrian, equestrian, bicycle movement, and recreation activities from automobile traffic

f. continuation of existing land uses and protection of land character, including buffer zone between incompatible land uses

Benefits to the Utility Company

a. improvement of public relations, including a change in the utility's public image

b. increase in public acceptance for future utility corridor construction

c. cooperation and economic and planning aid from government agencies

d. possible reduction in ROW purchase, construction, and maintenance costs and responsibility

It should be noted that the opportunity for benefits both to utility companies and to community residents would vary depending on the existing conditions. Therefore, possible benefits should be determined individually for each situation. In some situations, fee purchases or complex agreements with property owners for multiple-use corridors could conceivably lead to higher costs to utilities than would result from individual ROWs. Multiple-use planning with government agencies would ideally require full concurrence of property owners. There has been some evidence that adjacent landowners in densely-developed areas see a potential nuisance in recreational uses of ROWs.

If a corridor is planned initially for multiple use, a preliminary land use study should be performed in conjunction with planning bodies of the locality and should include consideration of:

a. ROW width available for multiple use

b. type of land title

c. type of utility corridor and corresponding compatibility factors

d. size and type of utility structure, including voltage, span and tower height of transmission systems

e. existing and future land uses adjacent to corridor

f. community needs

To avoid future jurisdictional disputes between the utility company and the community, written land use agreements should define development, maintenance, supervision and liability responsibilities. Public support of the project should be obtained before construction is allowed to take place. It is possible that residents adjacent to the corridor may be adamantly opposed to multiple-use development because of fear that the project will be accompanied by trespassers on private property, littering, noise, and vandalism. Proper precautions must be taken to prevent such potentialities from becoming reality.

Multiple-use development should coincide with community goals and have the support of the citizens. The ultimate success of multiple-use ROWs will depend upon their ability to satisfy community needs. Thus, potential multiple-use ROW development must be considered in relationship to adjacent land use. Although a given activity may be compatible with the utility line within a corridor, it may not be the best form of land use for a highly urbanized area. An orchard in an urban ROW may not be the most desirable multiple use because relatively few people will benefit from this type of development, compared with recreational development, which may be in greater demand.

Further discussion of the compatibility of multiple use with surrounding land uses may be found in Section V. The remaining discussion on multiple use will be directed primarily at land use relationships within the ROW.

In determining the suitability of multiple-use development, a satisfactory relationship between the multiple use and the utility as well as between the multiple uses themselves must be established. In the first instance, multiple-use considerations will tend to be of a technical nature in order to ensure safety for both the utility and the multiple use. However, it must be recognized that although two or more individual activities may be compatible with the utility line, the activities are not necessarily compatible with each other. As a general guideline, active and passive activities within the ROW should be separated from each other. Nature study trails may not, for example, be compatible with athletic fields or parking lots, although each of these multiple uses may individually be compatible with the utility.

An almost limitless selection of options is available for multiple-use development. For example, a study of the Southern California Edison electric transmission system reveals an unusually large assortment of multiple uses within their ROWs, including parkland; Christmas tree, pepper, sod, strawberry, and birds-of-paradise farms; plant nurseries; horse stables; lemon groves; and miniature golf courses (Southern California Edison, 1974). One particularly unusual innovation by the company is that of a calibrated hiking trail with emergency communications facilities for cardiac patients (McCrackin, 1974).

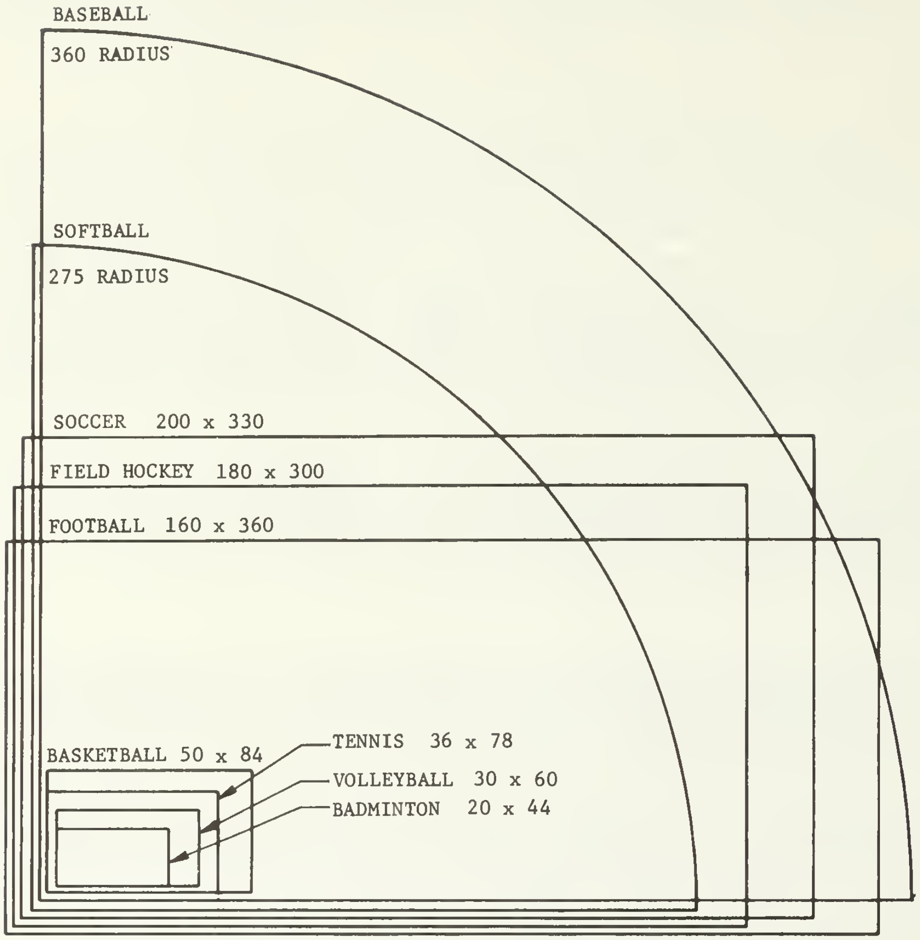
Potential multiple-use development of a ROW may be categorized as either recreational, agricultural, or commercial and industrial. Considerations for each of these categories are discussed below.

Recreation

Recreational activities may be divided into two general classifications, active and passive. As already mentioned, the compatibility of active and passive activities may be difficult to establish.

In comparing active and passive recreation requirements, it may be seen that suitability of active recreation has a greater dependence upon technical factors. Compatibility of active recreation will vary with the type of utility and utility structures. For example, in assuring the safety of recreational users of a ROW, kite flying is safe near pipelines, but may be a hazard below transmission lines. Similarly, the spacing between utility structures as well as the ROW widths provided may determine the type of field sports possible on the ROW; for example, baseball requires more space than soccer or football (see Figure VIII-1).

Passive recreation, unlike active recreation, relies heavily upon the quality of the surrounding environment. Suitability of passive recreation may thus be a more subjective consideration than in active recreation. Nature study may be more sensitive than playgrounds or field sports to the sight of transmission towers, pumping stations, or pipeline markers. However, the edge effect created by corridor location through forests may support more wildlife and a variation in vegetation, thus promoting recreation activities such as wildlife and nature study.



Notes:

(1) All recreation field maximum dimensions fit within even minimum EHV span lengths.

(2) Single transmission line right-of-way widths accommodate court areas, totlots, sitting areas and linear pathways.

(3) Double transmission line right-of-way widths are required for football, field hockey and soccer.

(4) Multiple transmission line right-of-way widths or higher kV range transmission rights-of-way are required for full size softball and baseball fields.

Source: Commonwealth Associates Inc., Guidelines For Development of Multi-Use Transmission Rights-of-Way, presented by Frank A. Denbrock P.E., Vice President, Energy Transport Systems Group, before the Edison Electric Institute, Transmission and Distribution Conference, Clearwater, Florida, January 17-19, 1973.

FIGURE VIII-1
FIELD RECREATIONS SPACE REQUIREMENTS

Potential recreational multiple uses include:

Active Recreation

- golf, miniature golf
- playgrounds
- athletic fields
- hunting (if no utility structures)
- equestrian trails
- bicycle trails
- snowshoeing
- cross-country skiing

Passive Recreation

- picnicking
- camping (in rural areas)
- nature trails
- wildlife refuge
- wild fruit picking
- hiking

Incompatible recreational uses include those activities that may endanger people, wildlife, or the utility system. These include activities that congregate large numbers of people in a fixed location or which involve heavy vehicles (both activities may increase erosion and thus threaten stability of the utility). In addition, activities that create a great amount of noise may disturb the wildlife or residents of the area. Specific activities that tend to be incompatible with utility corridors include:

- hunting (if there are aboveground structures)
- motorcycling
- snowmobiling
- fire building
- kite and model airplane flying (under transmission lines)

Agriculture

The introduction of small-scale agricultural activities (activities that do not require extensive irrigation, heavy machinery, or long a recovery period creating technical problems) may be highly compatible with utility lines. Agricultural ROW use may actually benefit the utility company by providing soil stabilization after ROW construction and maintenance. In addition, green space and gardening may be introduced in areas where such use was previously limited or nonexistent. Compatible agricultural multiple uses include:

- orchard, tree and shrub nurseries (height restriction generally 15 feet under transmission lines)
- Christmas tree farming
- sod farming
- strawberry and other small-fruit farming
- community garden plots

Commercial and Industrial Activities

Business activities that are highly sensitive to disruptions that may be caused by utility maintenance activities are not suitable within the ROW, nor are activities that may pose a threat to safety or reliability of either the utility or the business (as discussed in Section V). As a general guideline, multiple use should be restricted to commercial or industrial supporting functions, such as parking and, perhaps, storage (if nonflammable). Multiple-use potential of the corridor further includes development of green space to improve the esthetic impact of commercial and industrial development.

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SECTION IX
ROUTE SELECTION METHODOLOGIES

SECTION IX

ROUTE SELECTION METHODOLOGIES

SCOPE OF SECTION

This section presents a summary of methodologies available for use in determining the route or location of a utility line. The general requirements of route selection are first presented in terms of the procedural steps employed and the determinations made, together with a system of classifying methodologies according to the different procedures that may be used in individual studies. The various techniques are then illustrated by case studies that analyze the methods applied in determining the recommended location of four specific lines. Three of the case studies are of electric transmission lines and one reviews the proposed routing of an extensive pipeline.

AVAILABLE METHODOLOGIES

As used here, the term "methodology" means a sequence of systematic procedures for determining where a transmission line or pipeline corridor connecting two specific points should be located. The methodology enables the proponents of a line to screen out, from all possible routings, a single one for placement of the actual ROW. Although each study to locate a specific line contains many individual features, there are structural elements implicitly or explicitly part of all methodologies. Specific methodologies differ only in the manner in which these elements are used.

Factors Considered

Methodologies that are commonly used in corridor location studies usually employ some subset of the comprehensive set of factors considered in Sections III - VI. These factors are typically grouped into a few categories that reflect the criteria as to suitability of location employed by the methodology. All methodologies are likely to consider many of the broad physiographic features that represent engineering and/or environmental constraints. However, the extent to which such features as potential for ROW sharing are taken into account or the kinds of land use considered may vary between different methodologies and siting studies.

Level of Detail

The factors that influence choice of line location may be studied broadly, at a very fine-grained level, or somewhere in between the two. For example, the topography of alternative areas may be assessed broadly so as to distinguish regions in terms of general characteristics, recognizing that high mountains and rough hilly terrain tend to offer more engineering difficulties and a greater potential for adverse impact, such as erosion, than do gently rolling lands or level plains. On the other hand, individual factors may be considered, such as specific topographic and terrain features, degree of slope, and orientation or aspect (so as to distinguish between north- and south-facing hillsides). As another example, soil suitability may be considered by aggregating all the factors that determine it; or it may be analyzed in terms of fertility, texture, particulate size, drainage characteristics, etc.

A particular methodology is also characterized by how fine a geographic mesh is applied in analyzing the study area. Some methodologies divide the total region within which the line may be located into grids, the cells of which may be as small as 1/4 square kilometer, and identify the characteristics of each grid cell. Others consider the territory on a much broader scale.

Measuring or Otherwise Evaluating Factors

The factors that determine line location must be assessed on some basis that enables alternative areas to be compared. This assessment may be quantitative or qualitative. Quantification is normally based on actually measuring factors at some chosen level of detail, which may be quite broad, as in stating number of miles of each topographic region or kind of land crossed by an alternative route. On the other hand, quantification may address individual features, such as each of the factors combined in the Universal Soil Loss Equation which estimates erosion potential (see Section III). Qualitative assessment assigns descriptive terms indicating the suitability of an alternative area in regard to a specific variable or indicating the potential for some particular environmental impact. Qualitative assessment necessarily tends to be subjective. Sometimes it is combined with the use of numbers as when different types of terrain are ranked as to suitability on a scale from 1 to 10 or when susceptibility to erosion is similarly graded.

Means of assessment used by a methodology is necessarily related to the level of detail employed. Quantification is most easily applied to individual factors that can be measured, whereas aggregation tends to be associated with qualitative judgments made on the basis of an overall impression. Use of a small-scale grid is usually accompanied by quantification. A prime purpose of dividing the area into cells is to provide geographic units within which the significant factors are sufficiently homogeneous to be conveniently measured. Quantification of detailed characteristics and of small land units implies that the numeric values will somehow be combined to give a measure of suitability in regard to related factors over a segment of the line.

Operational Procedures: Steps and Products

Conceptually, the things that must be done in a utility corridor location study can be defined in advance, such as selecting the study area, collecting and organizing the data, assessing each potential corridor or route, and so on, down to making a final selection. It can also be expected that the selection process will proceed in stages to narrow the options, first with a study area, then with some set of defined portions of the area as potential corridors for further study, and, finally, a selection of one route from evaluation of several alternatives. However, individual methodologies differ as to the particular steps and the partial selection that are explicit in the process. It is instructive to examine such differences, both for their techniques and for the criteria used in the sequential decision making. Some methodologies make explicit such steps as defining the assessment criteria (implying group interaction and the opportunity for public participation or citizen input) and performing sensitivity analysis. Methodologies also differ as to the use of sequential decisions. In some, exclusion criteria may be successively applied to narrow selection, whereas in others calculation of suitability leads directly to selecting a final set of options.

The most common techniques used in the individual steps follow:

a. Use of maps of different types and scales to provide insight into the factors that will be encountered in the study area. Maps of the topography, hydrology, land use, ecology and demography of the area may be consulted.

b. Use of overflights and aerial photographs to observe and to show visually the variable features of the environment.

c. Use of overlays on which the key factors that determine suitability of a route are charted. These can be superimposed on maps of appropriate scale to block out areas unsuitable from an engineering and/or environmental standpoint and to indicate the paths with fewer problems. For example, the most difficult terrain conditions or land uses that are to be avoided may be blocked in some solid color on a transparent overlay and superimposed on a map. Those areas not covered are then taken as best from the standpoint of the particular condition considered. Different factors can thus be blocked in separate transparencies and then overlaid on the map. Those areas that admit maximum light then represent, in terms of the combination of factors, the best potential paths through the mapped area; while conversely, the darkest areas should be avoided.

d. Supplementing or substituting for overlays, the critical factors may be measured in some fashion and scores calculated to determine suitability of a specific alternative. For example, each route may be assessed in terms of the number of miles of wetlands through which it will pass, number of miles of wildlife habitat disturbed, number of major river crossings, and so on. Such a technique employs quantitative comparison, in regard to each factor used as a criterion for selection. The procedure also makes explicit the problem inherent in all selection methodologies: how to combine factors of different types and significance. Typically a weighting scheme is used in which the relative importance of each major factor (or category of related factors) is assigned a numeric value. The total significance of that factor is then the product of the weight and the measurement. For example, if wildlife happen to be assigned a weight of 0.2, the score for a proposed location that disturbed 50 miles of wildlife habitat would then be 10. The results for related factors (or for all factors used in discriminating among alternatives, if the weighting system is broad enough) can be summed to give a total score for a specific route.

e. A computer may be used in preparing the calculations as well as in portraying the results of map overlays, if coupled with a graphic output device. Some methodologies derive the scores for each alternative route by using a computer to manipulate input scores and values of factors as measured from maps, overlays, and field observation. They also print computer maps showing the results of conceptually overlaying areas blocked or shaded to show individual factors or combinations of factors. By selection of the symbols printed in these computer-produced maps, the best impact areas appear lighter than those where effect of the factor(s) considered will be greater.

f. At one or more points, on-the-spot observation of some portion of a proposed route is certain to be provided. This field inspection will be essential for the level of detail required to determine where the actual right-of-way might be placed. It is commonly used also at earlier stages to provide a better understanding of the effect of critical factors than can be provided by maps, overflights or aerial photography.

The operational steps and the intermediate products are closely interrelated because every partial selection (or narrowing of alternatives) clearly implies some operation from which the decision resulted.

Beyond that, however, there is admittedly some arbitrariness in dividing the process into discrete steps. For example, it would be clearly possible to treat the collection and organization of the data as representing a large number of distinct operations; but it seems more convenient to minimize the number of separate steps and to treat together all activities aimed at producing a particular result.

Dimensionality and the Final Decision

The final decision as to a single corridor selected could be made on the basis of a single criterion such as minimum overall environmental impact. Or it could take into account two or more criteria, such as cost, social impact, and physical-environmental impact. Where more than one consideration is involved, the decision may be up to human judgment as to how all are balanced. Or there may be specific rules for assessing them together. For example, if a low monetary cost is associated with a high adverse environmental impact and vice versa, it is perfectly possible to prescribe that the product of cost times impact be used as the single selection criterion.

Most methodologies appear to stop short of prescribing a single quantitative criterion for selection. In general, studies to locate utility corridors seem to rely on human judgment to assess the different considerations as well as to take into account any factors that may not be adequately represented in numerical scores of the top-ranked alternatives. In a judgmental decision it is never certain how many distinct criteria were explicitly evaluated. However, methodologies often incorporate some means of reducing the dimensionality: e.g., weighting the various environmental impact factors as to their relative importance so that the overall impact score represents the relative significance of the different aspects. Some methodologies do not weight the various environmental concerns, but treat them all as essentially equivalent.

Public Participation

The extent to which the public participates in application of a given methodologic approach might vary between the (theoretic) extremes of popular vote to select the recommended corridor or route to selection entirely by the utility company and its consultant(s) with no public input. Actually, observed methodologies appear to vary within much narrower limits, between public input by means of local planning groups to public participation at town meetings. With increasing participation by citizen groups in the public hearing and court procedures that often determine the acceptability of corridor location, it is important to consider the extent and timing of citizen input to the methodology.

There seem to be three types of public participation that have occurred in documented studies examined:

a. Indirect or representative, in which contact by the utility (and any consultants) is only with designated official or quasi-official groups, such as local planning boards, who may be considered to speak for the public.

b. Reactive, in which the only citizen input is through public hearings, where residents can comment on and express any objections.

c. Direct or contributory, in which citizen views and public preferences are actively sought early in, and as a significant part of, the planning process.

CASE STUDIES: INTRODUCTION

The following subsections present four case studies of methodologies used to determine the location for specific utility lines. Each study is examined from the point of view of line requirements, approach used, and principal issues at stake in any significant opposition that developed. An assessment is presented of the apparent success of each methodology in view of the problems encountered.

Table IX-1 summarizes the principal features of each case history examined.

TRANSMISSION LINES SERVING NORTHERN VIRGINIA

Overview

The problem of locating additional transmission lines by the Virginia Electric and Power Company (and the Potomac Edison Company of Virginia) to connect two new generating stations with the high demand area of the northernmost part of the state (adjacent to Washington, D.C.) involved integration of planned and existing facilities. The applicant originally took a very simple approach, using manual methods to locate the lines. However, the case was complicated by the fact that the applicant later engaged an environmental consultant to assess the probable impact; also, the State Corporation Commission (SCC) independently hired two consultants, who used computerized approaches, to recommend appropriate locations for a short stretch of transmission line between two specific points. The applications encountered intense opposition from environmentalists, spearheaded by the Rappahannock League for Environmental Protection (RLEP). No decision had been made by the State Corporation as of 3 February 1975.

TABLE IX-1

PRINCIPAL FEATURES OF FOUR CASE STUDIES

SPECIFIC STUDIES / KEY FEATURES	VEPCO	ONTARIO HYDRO	EDAP-PERMITS	NORTHERN BORDER
Type of Utility Line	Electric Transmission	Electric Transmission	Electric Transmission	Natural Gas Pipeline
Location	Central and Northern Virginia	Lennox-Oshawa, Ontario	Southern Wisconsin	Montana Border to Kankakee, Ill. and East to Pennsylvania
Approximate Length	Several lines: Longest 111 miles Shortest about 10 miles	100 Miles	Four lines comprising a system of about 110 miles	1600 miles (alternatives for about 2/3 of line)
Computerization	Not by applicant but by consultants engaged by State Corporation Commission	Yes	Yes	No
Alternatives Explicitly Evaluated	No	Yes	Yes	Yes
Public Participation	Consultation with local planning groups; public hearings	Direct citizen input to help define objectives, weight criteria and express values	EDAP-no direct input; PERMITS-input from meetings with representative groups	None Reported
Quantification of Factors	No	Yes	Yes	Partially: Count made of number of miles of critical types of land that would be involved
Weighting used to express relative importance of different considerations	No	Yes	Yes	No
Basis for Final Decision	General engineering judgment	Selection from best scoring alternatives	Selection from best scoring alternatives	Selection on basis of minimum impact on critical land types

Nature of the Requirement

Plans for nuclear generating facilities on the North Anna River in Louisa County, Virginia, and for a mine-mouth generating station along the south branch of the Potomac River near Petersburg and Moorefield, West Virginia, created a need for 500 kV transmission lines by which power from these new sources could be delivered to the northernmost part of the state to meet growing demands. A 32-mile line from the North Anna to a new substation planned at Morrisville, and thence about 10 miles to a substation at Bristers (both in Fauquier County) comprised the first part of the linkage. It was planned to interconnect with the generating station at Mt. Storm, West Virginia, by a 111-mile line to the proposed Morrisville substation (U.S. Atomic Energy Commission, 1973). The location of the facilities to be interconnected is shown schematically in Figure IX-1.

At issue were the following features of the proposed linkage:

a. Location of the transmission line from the North Anna to connect lines serving northern Virginia

b. Location of the substation proposed at Morrisville

c. Location of the line from Mt. Storm and its point of connection with the rest of the network

At issue with environmentalists was the applicant's stated need for separate transmission lines, based largely on reliability considerations (Jordan, undated), rather than upgrading or expansion of existing ROWs to provide the additional power transmission as recommended by RLEP. As part of their position, the environmentalists rejected the construction of a substation at Morrisville, which the applicant regarded as an essential part of the complex.

Methodology

Basic Approach

The applicant used a three-step approach employing mappings and overlays, in which final selection was based on engineering judgment and public input was limited to that provided by meetings with local planning boards and public hearings. The three steps were those typically used by the applicant: definition of a broad corridor, usually about 5 miles wide, although in some routing studies the width has extended to 10 miles; designation of alternative routes within the corridor; selection of a single line as optimum, based on best engineering judgment, in which the major environmental issues will be taken into account. For determining alternative routings within the corridor, overflights were conducted to observe the terrain and other natural and man-made features of significance. Aerial photographs were then studied. Field analysis

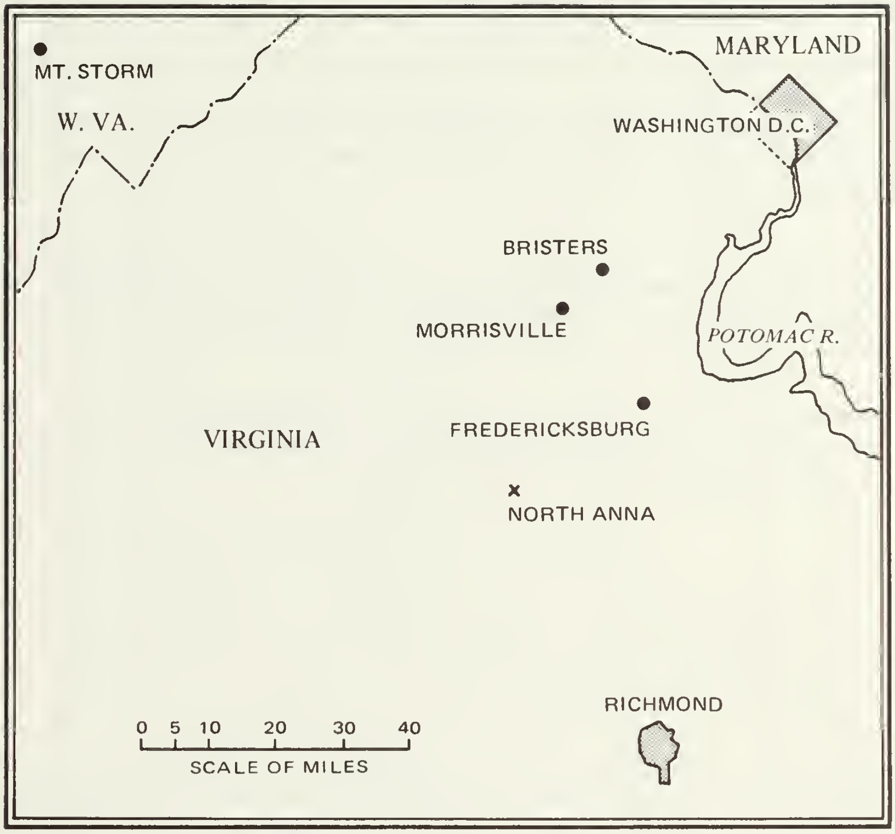

FIGURE IX-1

SCHEMATIC MAP OF STUDY AREA FOR VEPCO TRANSMISSION LINES of potential pathways provided a further refinement in defining, within a width of a few hundred feet, the possible centerlines of alternative routes and in choosing the single proposed pathway. The applicant viewed the process as essentially a sequence of engineering studies, keeping in mind ecologic and land use considerations.

Reservations About Computer Use

Representatives of the utility company informally expressed reservation about the use of a computer to help select transmission lines. Their preference for a methodology based entirely on mapping and field studies reflected three principal considerations (Virginia Electric Power, 1974):

a. Maps and overlays are better understood by laymen, who can observe and interpret them readily, without skepticism and mistrust of computer-produced results which typically require explanation by someone else.

b. Maps make a colorful and vivid display in which the results are more forcefully emphasized than in a computer graphic or tabular printout.

c. The effort required to collect data and process and prepare it for input to a computer is regarded as enormous, imposing an undue load in initial transmission line routing; furthermore, there is the problem that the data bank quickly gets out of date and requires costly allocation of manpower to maintain it.

Results of the computer runs provided by the two consultants to the SCC did nothing to increase the applicant's faith in computerized methodologies. On the contrary, the computer results were criticized as being unrealistic in their manifested inability to take necessary factors -- particularly buildings -- into account. The computer reportedly mapped routings right through town residences, too close to grange halls, and across the Rappahannock River at an unsuitable location. To some extent, such deficiencies clearly reflect the size of the grid employed (as discussed in the next section).

Public Participation

The typical procedure described by the applicant includes meetings with state agencies and with local (usually county) planning boards. These began early in the routing process, with the aims of making route selection compatible with existing and planned land usage and of avoiding areas most likely to be controversial. Many counties in the state (including at least one through which the lines were projected to run) require a specific use permit for utility lines. Public hearings were also conducted at the county level. Representatives of the utilities attended these to explain their plans, including the need for the additional facilities.

Historically, this method of interfacing on a representative, and sometimes indirect, basis with the citizenry had worked well. However, the applicant noted the increasing number of environmental considerations having to be taken into account. It also appeared that the degree of cooperation with the planning boards was less than perfect. In at least one instance (Virginia Electric Power, 1974), the applicant asked for five-year land plans prepared by a particular county board for use in determining the line location, but the request was denied. The applicant felt that, as a rule, the first step of the selection process worked well: there was seldom much trouble with the selection of a broad corridor; in the Morrisville-Bristers line, the applicant's proposed route as well as those of the SCC consultants fell within a very few miles. The controversy arose in regard to locating a specific ROW. Hearings normally came after the selection had settled upon a single ROW (or a very few alternatives) so that the public had no direct way to influence the initial location of the actual centerline. The applicant felt that it was best to go before local planning bodies with two or three alternative routes from which selection will be made.

However, in regard to long routes, there may be a need to reach agreement first on selection of a corridor. The Mt. Storm - North Anna complex appears to illustrate this problem. Opposition by the environmentalists centered on insistence that, rather than a new ROW physically separated from existing lines, the route should have paralleled existing facilities, upgrading them or extending them into a wider corridor. The applicant, as previously noted, felt that it was important to have separate facilities in order to provide greater reliability and decrease vulnerability of the system to the results of any disaster affecting circuits in a given location.

The applicant also recognized that its timing was wrong in engaging an environmental consultant. If such a study was to be made, it was realized that it should have been made early and a report submitted along with the proposal. Otherwise, a question of credibility tends to arise, with actual and potential opponents of the projected route seeing the environmental study as an attempt to justify ex post facto the chosen location, rather than as an objective study of environmental effects.

Consultants' Approach

The environmental consultant engaged by the applicant used a two-phased approach: first, to find a broad area or corridor within which a given segment of line might be located; second to determine location more exactly within such a corridor. In the two phases, U.S. Geological Survey maps of different scale were used, with overlays of environmental features.

The consultants employed by the SCC used an interrelated computer approach based on the 7½-minute topographic quadrangle maps of the U.S. Geological Survey. These maps are on a scale of 1" : 2000'. Each quadrangle was subdivided by a grid system into cells of about 25 acres for coding computer input. A common structural approach was used to combine two sets of criteria into a single study. Economic and engineering considerations were intended to find a least-cost path within selected environmental constraints between the two points defining each line. Economic costs were converted to dollars per acre so that the total cost of each grid cell could be determined; the overall cost of a given path was obtained by summing the cells which comprised it. Potential environmental impacts, based on a complicated set of constraints, were assigned dollar values based on relative significance of each set. The computer used a standard algorithm to trace, from a given starting point, the continuous path to which the minimum cost was attached.

Having university connections, consultants for the SCC in this study reportedly employed graduate students and their spouses to obtain data from county tax records, from maps, and from field inspections of the areas involved.

Details on the factors considered are given below.

Factors Considered

The factors used as criteria in determining line locations have to be considered in subsets, because of the separate studies made by the applicant and the various consultants. While there was some overlap among the factors considered, they tended to be quire different because of the diverse emphases involved.

Applicant Considerations

The applicant primarily used engineering considerations, with an attempt to avoid locations where the potential for environmental impact was most readily apparent. These included particularly historical sites, parks and national forests, and places with high visual exposure for the line. The utility expounds a policy of keeping the lines out of sight as much as possible. Minimum cost and system reliability figure prominently in the applicant's criteria; the latter consideration was particularly influential in opposing the idea of paralleling or upgrading existing lines to put the new facilities on a common ROW (Jordan, undated). Utility officials also stated that upgrading of an existing ROW can be very costly.

The company felt that the personnel were sufficiently familiar with the areas served so that they could make selection of a route that was satisfactory both from an engineering and an environmental standpoint. It seemed to be the utility's point of view that best engineering practice and minimum impact on at least the major features of the environment are compatible. Many of the constraints adopted for engineering and economic reasons, such as avoiding steep slopes where erosion is most likely, costly clearing operations, or acquisition of land valuable for other purposes, also lead to reducing environmental impact. Interpretation of environmental protection by the utility, which is required by state law, is based largely on the Federal Power Commission Guidelines. Utility officials have found difficulty with guidelines generally from two standpoints. Their legal status is somewhat questionable, so that it is not clear how closely they must be followed or what assurance of an acceptable routing is afforded by close attention to them. Also, the impressionistic nature of some guidelines almost ensures controversy, such as the question of how "far away" from a historic site or scenic feature a line must be located.

The applicant felt that its consultation with planning groups should have given enough attention to land use considerations. It is not the practice to take into account the strength of public opposition expected to develop against location of a line or of any specific segment. Utility officials suggested that the courts might hold them guilty of "arbitrary and capricious" actions if routing were so influenced. A similar point of view was expressed by the Director of the Division of Public Utilities, SCC, in testifying on the application, when he quoted from the 1970 report of the FPC task force that "locations should be determined by the broad public interest rather than by which route is cheapest, or which party can garner enough force to shift the burden to his neighbor" (Jordan, undated).

Consultant Engaged by the Applicant

The consultant retained by the utility based his survey of the proposed routing on environmental considerations related to the following factors:

a. Land use

b. Historic and recreational features

c. Vegetation

d. Stream protection

e. Soil protection

f. Visual aspects, particularly natural backdrop and exposures

It is the standard practice of this consultant to cross-check the environmental factors that he considers against those on the FPC guide-list relating to selection and clearing of a ROW and to location of transmission towers and overhead lines. Specific factors are considered from the standpoint of how they may affect existing and proposed land use; natural features of the environment, such as slopes and hydrology; and visual or scenic aspects.

Economic Determination of "Least-Cost" Route

Construction costs were used as a surrogate for all economic factors in the study of "least-cost" routes by the SCC consultants. These comprised the following categories (Strobl, undated):

a. ROW clearing costs

b. Line construction costs

c. ROW cleanup costs

d. Probable extra costs or road screening

e. Line maintenance

f. ROW acquisition costs

Estimates for construction and maintenance costs were based on data supplied by the applicant, taking into account terrain differences using rather general classifications of rolling, hilly, or mountainous. Line and tower costs by terrain type were based on the assumption of standard tangent-type towers of uniform height and fixed length of conductor span. The greatest controversy centered around the last item on the above list--ROW acquisition costs, which were based on an estimate of market value. In arriving at these costs, maps and records in local tax offices were used. The maps were superimposed on the grid structure derived from the USGS quadrangle maps. The land acquisition cost ascribed to a particular grid cell was usually based on the estimated value of the largest plot of land dominating the cell. In order to factor in the higher cost of improved land, the cost of the most expensive plot could also be included. Where a number of plots were equally represented in a grid square, the average value of all was used.

In order to screen out areas recognized as "forbidden zones," through which it was desired to exclude a line or minimize its intrusiveness, an arbitrarily high dollar value (99,999 per acre) was assigned to cells forming part of, or characterized by the presence of (Strobl, undated):

a. National parks (chiefly those associated with battlefields)

b. Extensive water areas (including reservoirs), where these covered as much as 50% of a given cell. (It was recognized that some water crossings might be inevitable and it was desired to minimize the amount crossed.)

c. Towns and cities

d. Cemeteries and schools

Least Environmental Impact

In developing environmental constraints to be used with the computer algorithm, features deemed significant were classified into six sets, termed "first-order constraints, second-order constraints," etc. Dollar values were assigned to the grid cells characterized by these constraints. The assigned values were intended to represent the relative importance of avoiding the different "orders" of constraint and were based, in the first instance, on the expense to which the applicant might be put if the constraints were violated. That is, the first-order constraints were assigned a value of one million dollars, taken as the approximate cost of running a high-voltage line underground for the distance of a cell. The consultant regarded values assigned to other orders of constraint as somewhat provisional, to be refined in subsequent development of the system.

The features so used are shown in the following list (Giles, 1973):

a. First-order constraints, or major protected areas:

    registered historic sites

    Federal transmitter zones

    airports with appropriate flight lane clearances

b. Second-order constraints, unacceptable as areas for a transmission line:

    scenic easements

    national parks and forests

    public gamelands and other natural areas

c. Third-order constraints:

    submerged marshes

    state-owned natural resources, such as beaches private, non-commercial recreational areas

slopes of greater than 5°

d. Fourth-order constraints:

existing recreational trails

areas recommended, but not yet officially accepted, for preservation, such as historic sites, scenic easements, or recreational resources.

e. Fifth-order constraints: locations such as residential and urgan areas which the affected population might be willing to give up for compensation

sites having some potential recreational or historic value but regarded as having a low probability of being designated as a public resource.

f. Sixth-order constraints:

general outdoor recreational facilities

beaches and boat landings

swamps and wooded marshes

orchards

As can be seen, the list is heavily oriented towards land use and visual impact. Concern for possible adverse effects on the natural features of the environment is largely expressed through considerations of slope (where erosion rates may be high and site revegetation difficult) and wetlands protection.

Opposition and Issues

Applicant Proposals vs. Consultants' Proposals

Although the methodologies differed drastically in approach and the criteria used for selection showed significant divergences, the applicant and the consultants engaged by the SCC agreed on a common goal: the most suitable locations for new transmission lines that would bring power to meet growing demands in northern Virginia. In prepared testimony (Ileo, undated) given at hearings before the SCC, one of the consultants went into considerable detail justifying the utility's estimates of heavy future power requirements.

In testimony before the SCC (Ileo , undated) the consultants stated that their computer runs had accomplished the intended purpose: selection of least-cost transmission line paths within the set of environmental constraints. These were seen as more economical than the routings proposed by the applicant. In particular, the line from Morrisville to Bristers was stated to involve an estimated cost of about $3000 less than the applicant's route, although it was about one mile longer. The computer-selected line avoided a Federal transmitter zone through which the utility's proposed routing would go. In addition, it was cited as crossing fewer roads, using less hilly terrain, avoiding more cultivated land (as well as an expensive land area in Morrisville) and paralleling an existing corridor (Strobl, undated).

On the other hand, the representatives of the utility were less than enthusiastic about routings developed by the computer. The objection has already been noted that the line passed right through housing areas and too close to grange halls. The computer methodology was criticized as being limited to orthogonal routings (rather than the shorter diagonal equivalents). There were questions as to the accuracy of superimposing the grids on tax maps, which were on different scales and orientations, as well as the timeliness and accuracy of the tax assessment records. Testimony at hearings before the SCC gave rise to some controversy over the land values used.

Attack by Environmentalists

Objection by environmentalists -- spearheaded by the Rappahanock League for Environmental Protection (RLEP), joined by the Culpepper Environmental League and others -- was made against the whole concept of new transmission ROWs. Opponents attacked the applicant's proposals with varied arguments, ranging from criticism of the methodology used in running the preliminary line surveys to criticism of transmission lines in general. In direct testimony given before the SCC, the environmentalists (RLEP) took the explicit position that a line should always be upgraded to provide additional capacity required or, if it were infeasible to do so, the ROW should be expanded so as to add an additional line. The basis of the utility's position on reliability came under attack as the key element in attempting to justify new ROWs.

Fundamental in the arguments of the environmentalists was the tenet that the transmission lines should always be planned with concern for the environmentaparamount to all other considerations, economic and technical. The environmentalists sought recourse to FPC guidelines regarding priority to consideration of expanding an existing ROW. They cited evidence from a special fly-over of the area conducted to show that there was room to add a new line adjacent to the old.

In this connection, charges were made that the applicant's proposal involved environmentally critical areas, with slopes greater than 20 percent; that 55 to 65 percent of the area comprised heavy to moderate timber, the loss of which would be severe and would contribute to pollution as a result of burning during clearance; and that it would result in extensive silting of the Rappahannock River. Witnesses also identified unsuspected points of potential historical interest affected by the proposed routing.

In regard to the Mt. Storm - Morrisville line, economic considerations vied for emphasis with concern over the scenic beauty of the region affected. It was predicted that the proposed line would end the rapidly rising land values of acreage sought for recreational and retirement homes and would limit options for future development of the area. The high visibility of transmission lines was described as marring the scenic beauty of the uplands, extolled as the region's most valuable asset.

Perhaps the ultimate dilemma was posed for the SCC in the statement of one witness (RLEP) that there is just no way "for an adverse use of land such as a utility corridor to ever be environmentally acceptable."

Assessment

No decision has yet been rendered, so it is not known whether the approach employed by the applicant was successful in selecting an acceptable transmission line routing. It appears that the utility chose a simple and standard methodology, emphasizing engineering considerations, which had been adequate in the past. As applied here, however, it encountered unforeseen difficulties in a situation made more complex by a changed emphasis among the criteria and by the entry of new forces of opposition. The increased significance of ecological and esthetic factors coincided with a different view of land potential in the affected area. Much of the most significant opposition, as manifested in the testimony before the SCC, was led by residents whose primary orientation was dictated by their professional and commercial interests in the Washington metropolitan area and who viewed the affected region in terms of its potential for recreational and retirement land use. The applicant admittedly prejudiced its own case by the time at which the environmental consultant was brought in. Officials of the utility stated the importance of making such a study before selecting a final proposed location.

What differences in results might have come about from a totally distinct approach remain a matter for speculation. The close proximity of the routes -- particularly between Morrisville and Brister -- as proposed by the applicant and by the SCC consultants suggests that different methodologies for routing new lines tended to produce similar results. The SCC consultants knew that the computer runs were imprecise as to actual centering of the ROW, as is clear from their testimony before the commission. Final determination, they stated, of where the line ran would have to come from on-the-spot survey. Thus, the utility's criticisms of the computer results (specified only within width of the 25-acre grid cells) might be resolvable, with the final result being convergence on a specific ROW that would be very close to both proposals.

It is clear that no methodology for locating a new ROW would satisfy opponents who strenuously protest that an existing corridor must be used. The issues in this case underline the importance of a procedure that assesses the merits of expanding a ROW compared to alternative new locations, taking into account the requirements for system reliability as well as relative costs and environmental impacts. The applicant's position rested primarily on standards of reliability which dictated a wide separation between transmission lines linking the same two points. The environmentalists' documented attack on this position contains both weaknesses and strengths. It may be a logical fallacy to charge (as the environmentalists did) that high reliability of the individual line is of no significance because it cannot affect subsequent portions of the system over which power must be delivered. On the other hand, the environmentalists' citation of numerous transmission systems operating satisfactorily with multiple circuits in a single corridor or on adjacent ROWs has merit. They also noted that the applicant's system within the area showed a statistically high reliability that could tolerate doubling-up of redundant links in the transmission network.

Both demands for transmission lines and competition for land use can be expected to increase significantly in the coming decade. Consequently, the alternative of expanded and upgraded ROWs will assume additional importance, requiring adequate procedures to assess it.

ONTARIO HYDRO 500-kV TRANSMISSION LINE

Overview

Ontario Hydro retained the U.S. firm of Commonwealth Associates to assist in developing a methodology for selecting a suitable transmission corridor that would link two stations north of Lake Ontario. A diversity of interests and of land uses was recognized and it was decided to develop a recommended line routing with the aid of extensive public input, using a computer to manipulate data and find one or more acceptable locations. The project began in 1971 when Ontario Hydro conducted an environmental survey of the area. The first series of public meetings began in February 1973. Strong opposition to part of the proposed line developed, particularly by agricultural and conservation interests. Actual construction has not yet occurred as the final ROW selection was, at last report, still in process.

Nature of the Requirement

Ontario Hydro was faced with the need to link the Generation Station at Lennox, Ontario, with a proposed Transformer Station at Oshawa, about

100 miles almost due west. A 500 kV line was planned. The study area consisted of about 1400 square miles, bounded on the east and west by the townships of Richmond and East Whitley, respectively, on the south by the natural boundary of Lake Ontario, and on the north by an extension east and west of Rice Lake in Hamilton Township. The region included farmland, several watersheds, scenic areas and some areas where suburban development was expected to spread westward from Toronto, but contained no urban centers.

Methodology

The identification of several 750-meter (approximately 1/2 mile) wide alternative corridors proceeded in four main steps:

- Specification of objectives of the line
- In-depth data collection
- Evaluation of data to determine responsiveness to each objective
- Generation of alternative corridor locations

The methodology, relying upon analytical procedures using a computer, was based on the assumption that any geographic area can be partitioned into cells of uniform size (specifically 250 meters square, comprising 15.45 acres), each cell having been characterized by natural and cultural conditions that gave it a degree of homogeneity. The key to the method was the measurement of suitability of a cell for location of a transmission line by means of an evaluation function:

$$S_{ij} = f\ (X_i, Y_j)$$

where:

S_{ij} = the suitability of cell i for transmission facility configuration j.

X_i = the set of variables that indicate the natural and cultural conditions and/or activities prevailing in cell i.

Y_j = the set of variables that describe the physical characteristics of transmission facility configuration j.

f = the evaluation function(s) that relate the values of the variables X and Y to S.

After the corridor alternatives had been generated, they were evaluated in terms of the objectives as well as in terms of political, social, and economic considerations brought into the process by a multi-disciplinary group of persons. Three alternatives were presented for further consideration, with a single route that combined some portions of all three ultimately recommended for adoption.

Public Participation

Instead of limiting public participation to public hearings after the completion of the planning stage (as frequently happens), Ontario Hydro incorporated public input throughout the planning process. The company goal was "to facilitate the flow of information concerning objectives and community values so that the project planning results would reflect the acceptable trade-offs" (Commonwealth Associates, 1974).

Vehicles for public input included controlled personal interviews, meetings with township officials and planning board members, public meetings involving the use of an attitude questionnaire, extensive publicity, mailing information to residents, public displays of material, mail-in "preference ballots," and spontaneous meetings with individuals and special interest groups.

As described by a spokesman (Ontario Hydro, 1974), Ontario Hydro went to the public three times during the study:

a. To inform the public of the study and to consider the whole geographic area, the methodology, the factor input, the objectives, and the weightings;

b. To get reaction on the three alternative corridors that had been mapped out as to location; and

c. To consider a specific ROW within each corridor at a detailed level.

Selection of Alternative Corridors

Data were collected from various sources, including maps, surveys. and census results, and coded for the grid cells. From these data the suitability of the various cells was determined as follows:

a. For each cell, inventory variables relevant to each objective were translated into a suitability score on a scale of 1 to 5 (5 expressing greatest suitability).

b. Exact suitability values assigned to each variable according to its suitability in satisfying the objective were determined by a multi-disciplinary team of professionals using citizen input.

c. For each cell, the suitability value of each objective was mapped by the computer. Composite maps were made for each township by weighting the objectives according to the values expressed by the citizens of the area.

The resultant maps were then visually analyzed for spatial distribution of suitability scores. This analysis yielded a set of three alternative corridors.

Factors Considered

Factors considered by Ontario Hydro included topography, surface hydrology, existing land use, existing roadways, communications and utilities, proposed land use, unique features, outdoor recreation suitability, average soil suitability for agriculture, and suitability for waterfowl. Using these factors or variables and citizen input, a matrix was devised to relate the suitability of variables to objectives. Variable-objective suitability scores were based, in part, on the results of public surveys using questionnaires and on expression of public preferences at local meetings.

The objectives in relation to which suitability scores were computed consisted of the following:

- Minimize damage to natural systems
- Minimize conflict with existing land uses
- Minimize conflict with proposed land uses
- Minimize conflict with culturally significant features
- Maximize potential for ROW sharing
- Minimize visual exposure
- Minimize conflict with suitability analysis.

Issues and Opposition

None of the three proposed alternatives was wholly acceptable to the public, particularly at the western end of the line. A fourth alternative was suggested, which was studied by Ontario Hydro. Then, when hearings were held before the commission charged by the Canadian Government with responsibility for approval of a line, the public suggested two more alternatives for the western end. These represented more southerly routes, based on a sort of corridor concept in that there were already a major highway and railroad there. Ontario Hydro had located the corridor away from the highway for esthetic reasons; however, the commission wanted these areas studied and engaged a consulting firm to make a separate analysis.

The study area consists largely of rural regions. Ontario Hydro's approach had been to avoid urbanized districts. In the southern area near the Lake Ontario shore, land developers had a strong interest in wishing to keep transmission lines out of regions where the suburban spread from Toronto is expected to take place. As binding constraints on line location, Ontario Hydro precluded the use of the best farmland as well as swamplands and natural conservation areas.

The principal blocs with which Ontario Hydro had to deal were the farmers and agriculturists on one hand and the naturalists and conservationists on the other. These two groups had opposing views that were largely incompatible. The Sierra Club originally promoted opposition and tried to push the routing away from natural areas onto farmland. But the farmers represent a very powerful force that, through farm unions and their government representatives, has been making itself felt even more effectively than the conservationists. Although, on the average, only about 0.1 acre per tower would be lost to agriculture, the farmers appeared very much concerned about this land and were using the current concern over food shortages to block use of agricultural land.

It appeared that none of the interest groups involved in the controversy was really satisfied with the factor weightings contrived to reflect the values at issue (Ontario Hydro, 1974). This difficulty may reflect the fact that the issues over what kind of land to use are not readily reconcilable and that no one wishes to see his viewpoint absorbed into a weighting scheme. As seems often to happen, once a single line is selected as the recommended alternative, opposition from diverse interest groups consolidates against it. Conflicting interests that have been pushing in different directions up to that point can all see some objection in the route proposed and attack it on different grounds.

There was also some opposition to the use of a computer. The Canadian Ministry of the Environment flet that the method used lacked flexibility and criticized it on those grounds at the hearings. Ontario Hydro felt that objection to the computer methodology could be partly overcome by better programming, but also noted that, on the whole, the public does not like computerization. Many people do not understand, at least initially, computer-produced maps. Canadian nationalism also was a factor in objections made to the employment of a United States firm as consultants.

Assessment

Because no decision has, at latest report, been rendered, it is not possible to determine with finality the success of the methodology in selecting a route for the line. Ontario Hydro feels (private communication, 1974) that essentially the route as recommended will be accepted over about the easternmost three-quarters of its extent. It is not yet clear what the disposition will be for the 25 miles or so at the western end up to Oshawa.

Nothing in the analysis of the corridor location study (based upon written reports and on telephone conversations with officials of Commonwealth Associates and of Ontario Hydro) suggests that radically different results would have been obtained by another methodology. The most unusual feature of the approach used was the degree to which public input was sought and utilized. However, the final scoring system and set of weights were not based entirely on citizen preference, which constituted only one input evaluated by the Commonwealth Associates and Ontario Hydro study teams. Citizen input provided an interesting way by which slightly different value systems in each locality affected by the route could be taken into account. As a result, perception of the importance of different factors in individual localities was probably keener than it would have been without incorporation of public preferences. However, there was no indication that the values expressed by the public were radically different from what the study teams would otherwise have perceived. It is perhaps disappointing that nothing in the methodology seems to have been effective in facilitating a compromise among sharply conflicting interest groups.

Ontario Hydro still believes strongly in the methodology and is pushing actively to extend its use in future routing studies. Despite some opposition to computerization expressed at governmental levels and by the public, current plans are to increase the role of the computer. In the Lennox-Oshawa study, the actual ROW was picked within each general corridor by manual means from photographs and on-site investigation. In the future, it is envisioned that the computer will be used to specify a more precise location within the corridor, even down to a specific ROW. Ontario Hydro officials appear to have abundant faith in the ultimate capability of the computer to provide the necessary comprehensiveness, to do rapid testing of new proposals as these come up, and to perform sensitivity analysis by varying weightings and incorporating alternate sets of values or measurement of factors. In contrast to the expressed concern of the Ministry of the Environment, they see the computer as capable of giving more flexibility than is possible by strictly manual techniques and regard the problem as one of effective programming. Ontario Hydro is developing its own set of programs for future use. This operation is envisioned as combined with establishing a computerized data bank that would be continually updated for use in utility line location studies.

They also see the need to provide results in a form that will be readily understood by the public through the use of the more standard overlay maps.

There seems to be some disappointment on the part of Ontario Hydro with the methods used to obtain public input, particularly in subsequent application of the open meetings employed in planning the Lennox-Oshawa line. These meetings reportedly failed to produce the desired exchange of information and views seeking to arrive at a consensus, but tended instead to turn into political rallies. A better way is now seen in the establishment of information centers in townships to be manned by members of the project team with maps and data to facilitate one-to-one and small group discussion. It is also envisioned that the study teams will meet with citizen committees where dominant views on values and suitability affecting routing can be explored with responsible representatives in order to provide input to the computer algorithms that score alternative locations.

EDAP - PERMITS

Overview

The Environmental Decision Alignment Process (EDAP) is a general computerized procedure for selecting transmission line corridors. It was first developed by Landscapes Limited for the Wisconsin Power and Light Company and Madison Gas and Electric Company for the purpose of routing four 345 kV transmission lines through southern Wisconsin.* When these companies took the results to the public, they encountered opposition that finally led to the rejection of the proposed routes. The corridor finally selected was one subsequently proposed by the power companies after hearings before the Wisconsin Public Service Commission.

Since its initial application, EDAP has been modified and is now being tested in its new form, called PERMITS (Process of Energy Routing Minimizing Impact from Transmission Systems), by the Bonneville Power Administration (BPA) in the Pacific Northwest. One of the aims is to make PERMITS more acceptable to the public by greatly enlarging the input from public representatives at early stages in the planning process.

Nature of the Requirement

EDAP was originally developed for the purpose of routing transmission lines from the Wisconsin Power and Light Company Columbia Generating Plant, south to four substation terminals, extending almost to the Illinois border. The system was to be approximately 110 miles in length. The desired system included:

a. A double-circuit 345-kV system between the power source at Columbia and the Wyocena tap.

b. A single-circuit 345-kV line between Columbia and the North Madison substation.

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* Landscapes Limited was founded as a firm of consultants by Professor Philip Lewis and other members of the faculty of the Department of Landscape Architecture, University of Wisconsin.

c. A single-circuit 345-kV line between Columbia and the Rockdale substation.

d. A single-circuit 345-kV line between the Rockdale substation and the Paddock terminal.

Methodology

Instead of translucent map overlays, this routing method uses a large-scale computerized approach with a very great capacity for data storage and manipulation. Devisors of the methodology hoped that the computer would provide a more systematic approach taking into account interaction among the variables. The EDAP method consists of the following:

a. Inter-Group Constraint Seminar

Interaction among the clients, consultants, and various experts defines the scope and intent of the study. The area is divided into subregions with similar characteristics such as topography, weather, soil, geology and population density.

b. Information Review

Existing information contained in reports, maps, and other forms is reviewed.

c. Generation of Determinants

Important environmental considerations (including economic and social concerns) are defined in statements called "determinants," for example, "to minimize disruption to agricultural land use practices." Determinants correspond approximately to what are termed "objectives" in this report.

d. Generation of Variables, Data and Components

Hierarchical categories of factors are identified by the group of clients, consultants and experts; their interrelationship with determinants is defined.

e. Development of Data Bank

Data are collected from maps and photographs. Then the data are coded to characterize map grids of a selected size. Typically, 1/4 km square cells are chosen.

f. Formulation of Determinant Models

The basic block of EDAP is what is called the "determinant model," in which the contribution of the various factors at different hierarchial levels is specified. These models represented further collaboration of the consultant with the client utility companies and selected experts.

g. Selection of Corridors According to Alternative Policies

Selection of a utility corridor is typically complicated by the fact that various institutions and citizen groups, each with its own interests and set of values, have a stake in location of the facilities. The utility's interests naturally do not correspond to those of environmentally oriented groups. The farmer's point of view will not coincide with that of the commercial land developer or the conservationist. EDAP made an explicit attempt to deal with this problem by defining what were called "policies"; each policy was intended to correspond to the point of view of a particular interest group (e.g., the Naturalist Viewpoint). Each set of determinants was weighted individually for each policy according to what was deemed to represent the value set for that viewpoint. An optimum corridor was then selected for each viewpoint in policy.

h. Selection of Right-of-Way

After defining a corridor, the centerline (exact path of the transmission line) is selected through detailed examination of low-level infrared aerial photographs of the corridor.

i. Management Recommendations

Appropriate resource management practices to minimize impact on the environment both during and after construction are selected.

Factors Considered

Seven determinants and 19 components were generated for the Wisconsin study. Each determinant was structured as a hierarchy composed of three sub-levels--components, variables and data. For instance, Determinant Six, Maximization of Compatibility with Potential Visual Exposure, was composed of three components: Extent of Potential Visual

Exposure; Extent of Potential Visual Access to Facility; and Potential Visual Screen. Table IX-2 lists the complete set of determinants and their components. At the next level, the component "Extent of Potential Visual Exposure" is composed of five variables, consisting of Potential Exposure from Rural Land Uses, from Recreation and Conservation Land Uses, from Water Systems Used for Recreation, from Highways, and from a Culturally Important Landmark.

In a similar manner, the variables are broken into data. The variable "Potential Exposure from Rural Land Uses" is composed of six data items. These comprise three sub-categories of rural residential suburban, rural, and agricultural--as well as rural commercial, rural industrial, and rural institutional. Each of these data is defined as the percentage of the 1/4 km^2 cell area that is occupied by the particular type of land use. Each determinant branches in a similar manner. There are a total of 119 data items used by the EDAP process as developed for the Wisconsin study.

After accumulating the data, each of the levels of the hierarchy is weighted and summed in a determinant model. Weights at a given level are assigned so that their total is 100. Figure IX-2 is an example of the weights given to a section of Determinant Six. Each of the data items is multiplied by its associated weighting factor and the resulting quantities are then summed. This sum is the value of the variable. The procedure is then repeated, and the variables are weighted and summed to arrive at the value for the component. A reapplication of the procedure is utilized to find determinant values. This process is repeated for every 1/4 km^2 cell in the study area, resulting in an array of values which are then scaled from one to ten.

The next and most critical step of the EDAP process is the combination of the determinants to select a corridor. This is accomplished by weighting the determinants and combining them in a fashion similar to the combination of data. Here the weights reflect judgment as to the subjective value system of different interest groups, rather than an attempt to define as objectively as possible the significance of different factors in determining a specific type of potential impact. The authors of EDAP defined four policies and several subsets, each of which entailed different weights for the determinants. The four main policies reflected attempts to represent the following viewpoints: the naturalists's, the farmer's, the politician's and the tourist's. The determinants were then combined for each policy and the sum of their weighted scores was computed as part of an optimization program to pick the best route for each policy. Each route, optimal on a particular basis, was then analyzed in terms of the total potential impacts and sensitivity to other viewpoints.

TABLE IX-2

DETERMINANTS AND COMPONENTS

Determinant One: Maximization of Compatibility With Urbanized Land Use Practices.

- Greatest Compatibility with Existing Land Uses
- Greatest Compatibility with Communication Systems
- Greatest Compatibility with Proposed Land Uses
- Greatest Compatibility with Zoned Land Uses

Determinant Two: Minimization of Disruption to Agricultural Land Use Practices.

- Least Disruption to Agricultural Land Use
- Least Disruption to Zoned Agricultural Land Uses

Determinant Three: Minimization of Disruption to Recreational Land Use Practices.

- Least Disruption to Existing Recreational Land Uses
- Least Disruption to Proposed Recreational Land Uses

Determinant Four: Minimization of Disruption to the Natural System.

- Tolerance of Vegetation to Impact
- Tolerance of Water Systems to Impact
- Potential Impact to Wildlife

Determinant Five: Maximization of Potential For Functional Right-Of-Way Sharing.

- Functional Compatibility With Existing Right-Of-Way
- Functional Compatibility With Proposed Right-Of-Way

Determinant Six: Maximization of Compatibility With Potential Visual Exposure.

- Extent of Potential Visual Exposure
- Extent of Potential Visual Access to Facility
- Potential Visual Screen

Determinant Seven: Minimization of Financial Investment.

- Minimization of Construction Costs
- Minimization of Right-Of-Way Procurement for Leasehold
- Minimization of Recurring Maintenance Costs

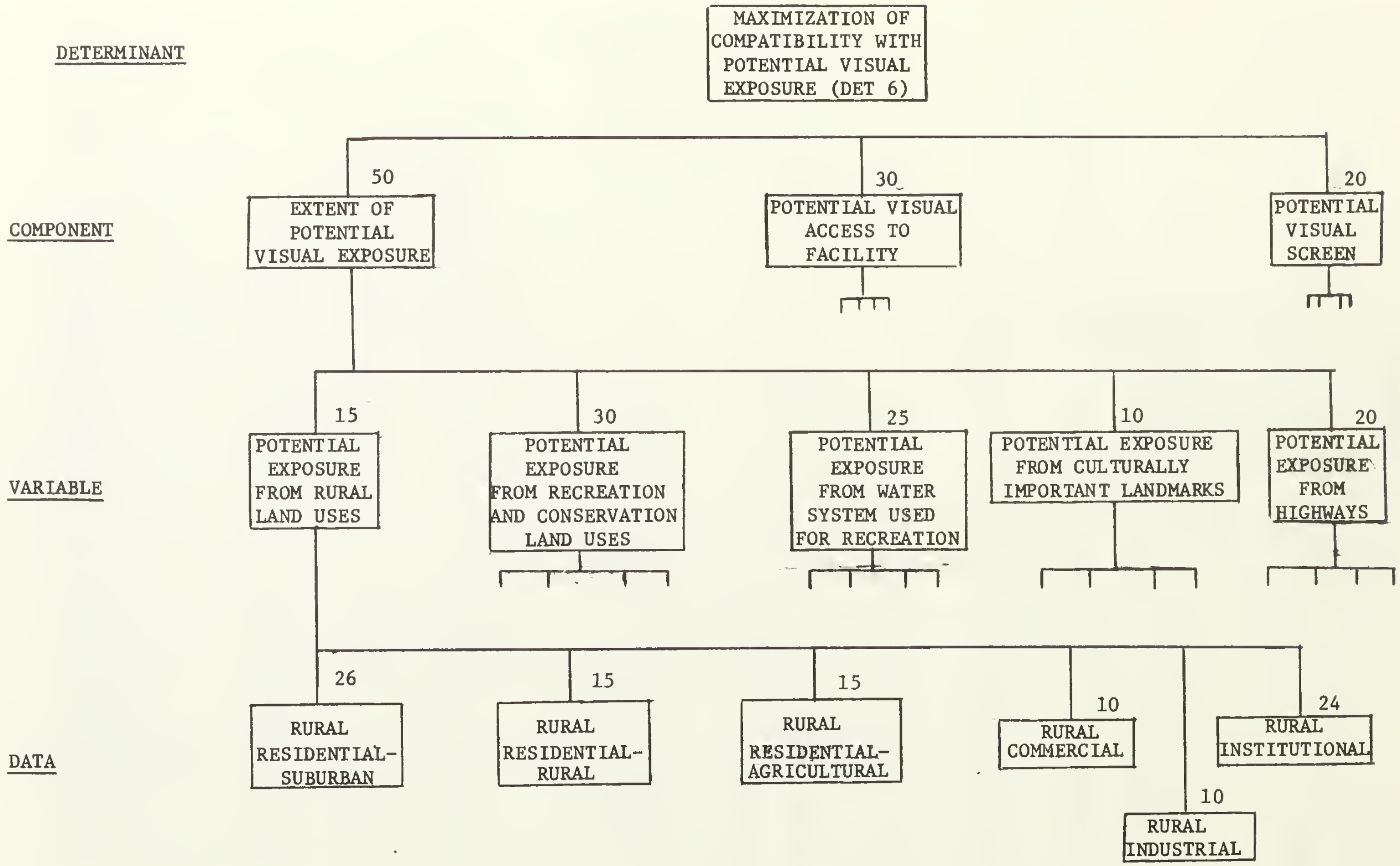

DETERMINANT
MAXIMIZATION OF COMPATIBILITY WITH POTENTIAL VISUAL EXPOSURE (DET 6)
COMPONENT
50
EXTENT OF POTENTIAL VISUAL EXPOSURE
30
POTENTIAL VISUAL ACCESS TO FACILITY
20
POTENTIAL VISUAL SCREEN
VARIABLE
15
POTENTIAL EXPOSURE FROM RURAL LAND USES
30
POTENTIAL EXPOSURE FROM RECREATION AND CONSERVATION LAND USES
25
POTENTIAL EXPOSURE FROM WATER SYSTEM USED FOR RECREATION
10
POTENTIAL EXPOSURE FROM CULTURALLY IMPORTANT LANDMARKS
20
POTENTIAL EXPOSURE FROM HIGHWAYS
DATA
26
RURAL RESIDENTIAL-SUBURBAN
15
RURAL RESIDENTIAL-RURAL
15
RURAL RESIDENTIAL-AGRICULTURAL
10
RURAL COMMERCIAL
10
RURAL INDUSTRIAL
24
RURAL INSTITUTIONAL

FIGURE IX-2

EDAP STRUCTURE AND WEIGHTING

Opposition and Issues

As reported by an official of the Wisconsin Power and Light Company (Daines, 1975), the application to the Wisconsin Public Service Commission (WPSC) for a Certificate of Authority (CA) presented three alternative transmission lines. One of these was a route chosen by EDAP as having minimal overall environmental impact. This choice represented a subjective judgment on the part of the consultants after considerable sensitivity analyses. The utilities presented two additional routes: one minimized cost without regard to environmental impact other than length and locational adjustments within the corridor. The other was considered by the utilities to represent a suitable compromise of the conflicting interests of the environment, costs, system reliability, and interests of the property owners. "Routes" as presented to the WPSC were one-half mile wide corridors, with the final ROW centerline to be located anywhere within the one-half mile width as determined by field conditions.

Two weaknesses in the EDAP methodology were particularly exploited by opponents of the recommended routes. The first was that the study had not actually involved public agencies or planning groups. All the inputs to the model, determining which factors were important and how they were to be considered, were internal to the consultant and the power companies. Even at the policy level, the weights were arbitrarily chosen and were merely assumed to reflect the desires of the various interest groups. Although outside experts in particular fields were called in to contribute their best estimates, none of these spoke in any official capacity or as spokesman for the public or for any citizens' group.

Although a spokesman for the Wisconsin Power and Light Company felt that the results were valid for the large number of corridors evaluated by EDAP, the results of the study as presented to the WPSC did not establish a sensitivity analysis for which the consequences of error in the data could be determined. This second difficulty was particularly important in view of the fact that the WPSC disputed the accuracy of some of the data used in the study. A related objection was that not enough time had been spent gathering on-site data.

The EDAP architects felt that both of these shortcomings could be relatively easily eliminated in a future application of this methodology, but they are aware of a more fundamental problem. EDAP is a computerized process. A machine is necessarily the main component of the system. There is often a public resentment against the idea that computers are dictating actions; this resentment, in turn, contributes to public dissatisfaction with the proposed actions.

While some of the proverbial "man-in-the-street's" vague dislike of computer-assisted decisions may be based on the unreasoning dread of a new and powerful unknown that has accompanied virtually every radical scientific innovation, thoughtful observers and policymakers have some valid basis for reservations. A computerized methodology, unless fully documented for laymen and interpreted in their language, can be hard to check and to validate. Since the results come to the outside user as a completed package, he tends to regard the computer methodology as "inflexible." Not unnaturally, public officials charged with any responsibility for a decision like to be able to test the method independently and to validate results.

In the application of EDAP to the Columbia lines, opposition to the computerized methodology was strongly entrenched at an official level. One spokesman for the WPSC who discussed the case expressed two strong objections: (1) a method based on gathering and summing discrete bits of information could not account for the various multiple interactions among the various factors; (b) the EDAP procedure was so complicated that it afforded no opportunity for WPSC to use the applicant's input for making an independent assessment. Together, these objections highlight the dilemma in providing a computerized program which is sufficiently comprehensive to address interactions and which can be made readily intelligible to policymakers called in to check results and test sensitivity.

Both the utility companies involved and their consultants are aware of this basic difficulty. A representative of the utilities stressed particularly the importance of public relations in making clear the methodology and how the computer results were obtained so that these can be analyzed reasonably in reaching an eventual decision. The designers of EDAP and the WPSC seem to agree on the difficulty of weighting the various considerations, particularly at the higher level where "Determinants" were combined according to "policies." Spokesmen for the utilities and their consultants stated that it had been a mistake to present such a limited number of recommended alternatives. There are no officially stated priorities for conflicting considerations by which weights actually representing an agreed-on value system can be assigned. They feel that, in any future study, a fairly complete set of alternative routes should be presented, with explanation of how and why each was optimum from some particular standpoint. The political process, which provides inherently for resolving mutually incompatible points of view, however, reached a consensus that a further difficulty existed. The most politically acceptable route (in the sense of giving minimum dissatisfaction to all concerned) might not be one that was "best" from any single standpoint. Perhaps some route that was "second best" according to several different criteria should ultimately emerge.

Extension into PERMITS

In an effort to develop an improved, more acceptable methodology, the overall model is now being extended by the Bonneville Power Administration (BPA) to areas of the Pacific Northwest. The result is PERMITS, a larger model that incorporates several features lacked by EDAP. The basic structure of PERMITS is shown in Figure IX-3. It is composed of four subsystems: location model selection; data bank development; corridor selection; and right of way selection. Some of the differences between the PERMITS and EDAP methodologies include:

a. PERMITS determinant models are selected to represent the significant characteristics of the particular area in which the study is being conducted. Twelve determinants have been identified for the BPA service area (see Table IX-3).

b. PERMITS includes a sensitivity analysis to determine the magnitudes of the effect of the various data items on the resultant determinants.

c. PERMITS also includes considerably more input from groups representing various public interests. This interaction occurs at three times: during selection of applicable determinants, during the policy formation seminar and at the public hearing.

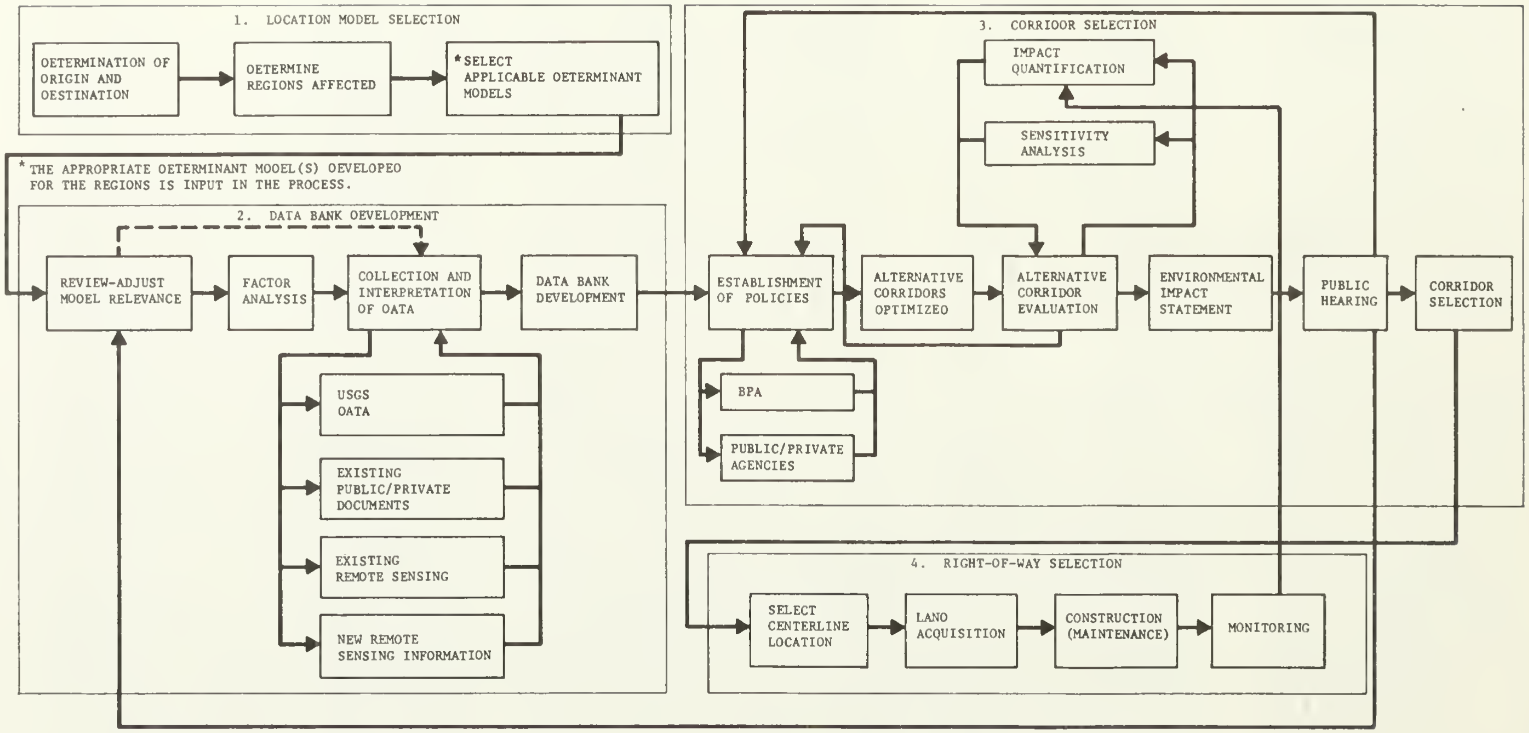
d. Once alternative policies are decided upon, an optimum route is developed for each. All of these routes and an Environmental Impact Statement detailing the impacts of each are presented at a public hearing, after which a single preferred route is chosen by a decisionmaking body.

It will be interesting to observe the extent to which, with appropriate public relations work, these changes make PERMITS a useful instrument in developing acceptable transmission corridors. Although data requirements and expense are great when PERMITS is used, public acceptability and decreased environmental costs of the selected corridor location should justify such expenditures.

NORTHERN BORDER PIPELINE

Overview

Six companies formed a consortium, known as the Northern Border Pipeline Company, to install a pipeline to bring natural gas from Canada and Alaska to the eastern and midwestern states east of the


1. LOCATION MODEL SELECTION
DETERMINATION OF ORIGIN AND DESTINATION
DETERMINE REGIONS AFFECTED
*SELECT APPLICABLE DETERMINANT MODELS
* THE APPROPRIATE DETERMINANT MODEL(S) DEVELOPED FOR THE REGIONS IS INPUT IN THE PROCESS.
2. DATA BANK DEVELOPMENT
REVIEW-ADJUST MODEL RELEVANCE
FACTOR ANALYSIS
COLLECTION AND INTERPRETATION OF DATA
DATA BANK DEVELOPMENT
USGS DATA
EXISTING PUBLIC/PRIVATE DOCUMENTS
EXISTING REMOTE SENSING
NEW REMOTE SENSING INFORMATION
3. CORRIDOR SELECTION
IMPACT QUANTIFICATION
SENSITIVITY ANALYSIS
ESTABLISHMENT OF POLICIES
ALTERNATIVE CORRIDORS OPTIMIZED
ALTERNATIVE CORRIDOR EVALUATION
ENVIRONMENTAL IMPACT STATEMENT
PUBLIC HEARING
CORRIDOR SELECTION
BPA
PUBLIC/PRIVATE AGENCIES
4. RIGHT-OF-WAY SELECTION
SELECT CENTERLINE LOCATION
LAND ACQUISITION
CONSTRUCTION (MAINTENANCE)
MONITORING

Source: Landscapes Limited, Permits Methodology, published by U.S. Department of Interior, Bonneville Power Administration, undated.

FIGURE IX-3
BASIC PERMITS STRUCTURE

TABLE IX-3

PERMITS DETERMINANTS

- Minimum disruption to existing urbanized land uses and human settlement.
- Minimum disruption to agricultural land use practices.
- Minimum disruption to recreational land uses.
- Minimum disruption to the ecosystem.
- Maximum utilization of right-of-way.
- Minimum visual impact.
- Minimum financial investment.
- Minimum disruption to forestry practices.
- Minimum impact upon projected human settlement.
- Maximum system reliability.
- Maximum accessibility.
- Minimum disruption to extractive and storage resources.

Dakotas. Manual means, employing maps and aerial photography, were used to define three prospective route alternatives as far west as Kankakee, Illinois. Based on an analysis of the extent to which each of the alternatives impacted on selected critical environmental features (principally the mileage involved in crossing each of four types of areas), one of the proposed routes was selected and, after minor changes in location, was recommended as the Preferred Route (PR).

Nature of the Requirement

The pipeline is required so that natural gas from Canada and Alaska delivered at the northern border of the United States can be distributed in the East and Midwest. The pipeline originates at the Canadian border near the town of Monchy, Saskatchewan, and extends approximately 1600 miles, across 10 states and 76 counties, to its eastern terminus at Delmont, Pennsylvania, near Pittsburgh. Beginning with a delivery rate of 1.2 billion cubic feet per day (CFD) during the first year of operation, the line is expected to increase the delivery rate in the second year to 2.2 billion CFD, with an ultimate capacity of 3.5 billion CFD.

Methodology

As reported in the applicant's Environmental Assessment (Ecology and Environment, Inc., 1974), alternative routes were considered only as far east as Kankakee, Illinois (see Figure IX-4). A very simple methodology was employed in route selection, using aerial photography to map prospective corridors about 4.5 miles wide within which the exact ROW would later be located. The shortest great-circle route forming a straight line on the map represented one obvious possibility (designated as Line 3 in the Environmental Assessment). A second, more southerly, route with a pronounced obtuse-angle bend southwest of Pierre, South Dakota, comprised a second possibility (Line 2). As seen on the map, these routes form a scalene triangle enclosing (except for a small stretch near the Montana - North Dakota border) the alternative (Line 1), which, with slight modifications, became the chosen preferred route (PR).

Assessment of the routes and final selection were made by analysis of the engineering and environmental considerations. To a considerable extent, these concerns seem to have been compatible in that factors such as erosion potential, wetlands exclusion, and minimal river crossings represented both environmental and engineering constraints that often coincided as reasons for eliminating particular areas. Length was not an important factor, as there were fewer than 100 miles of difference between the longest and shortest routes. The southernmost route formed a sort of natural boundary to the study area. In this connection, it was deemed that to extend it farther southward so as to avoid unacceptable

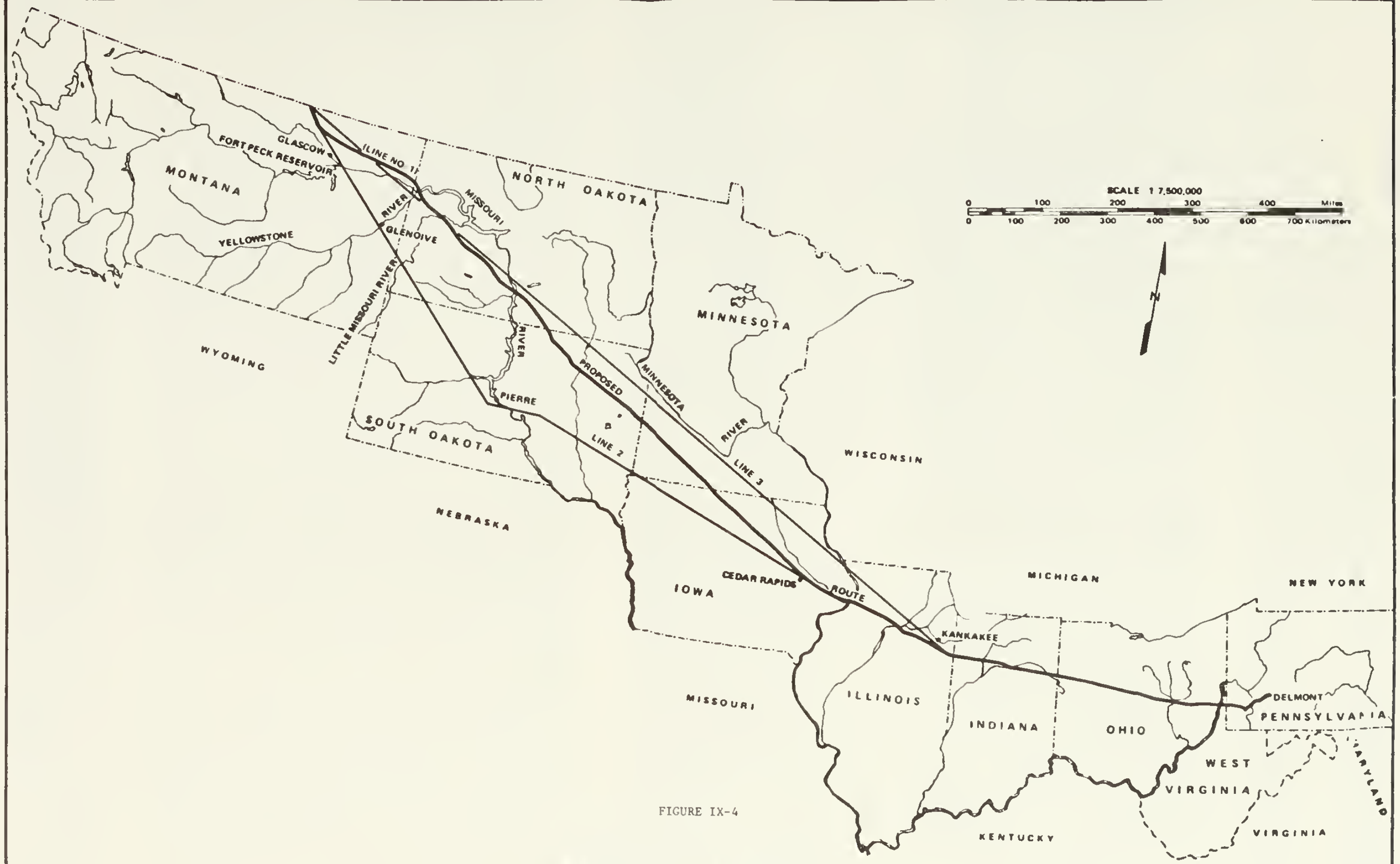


FIGURE IX-4

PROPOSED ROUTE AND ALTERNATE LINES

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environmental impact along the fragile rangelands and badlands would result in unnecessary increase in length.

The route initially selected (Line 1) was chosen primarily on the basis of least environmental impact, compared to the other two alternatives.

While Line 3 was early judged to be inferior to the other two in terms of its environmental impact, neither Line 1 nor Line 2 "dominated," in the sense of being better in all major environmental considerations. When trade-offs were considered, applying the various factors to what were deemed the critical features encountered as discussed in the next subsection, Line 1 was judged superior. Small modifications in the routing as originally studied were then proposed to minimize environmental impact, in particular to reduce the number of miles of passage through rangelands and badlands in the northwest, which resulted in the path recommended for adoption as the "preferred route."

Factors Considered

Categories and Detailed Features

Most of the major categories of factors discussed in Sections I - VI of this report were taken into account in assessing the probable impact of the pipeline and selecting a preferred route: Table IX-4 lists the specific features that are discussed in the Environmental Assessment, Section 8.3, Alternatives to Routing (Ecology and Environment, Inc., 1974).

Physiography and soil conditions were of concern in minimizing the extent of the pipeline through areas where the terrain was fragile and erosion would be high. Revegetative capacity was regarded as an important factor. In this connection, a specific area was looked on with disfavor because the high sodium content of the soil made revegetation difficult. Thinness of soil with bedrock lying close to the surface provided a constraint from the environmental standpoint and also increased construction difficulties through the implied need for blasting. A high water table associated with the presence of standing water in surface bodies ranging in size from seasonal potholes to all-year lakes raised difficulties for pipeline construction; these areas were also undesirable because of the potential impact on hydrology of the region. Secondary considerations included preservation of the wetlands as a waterfowl habitat and the danger of interfering with the recreational activity of cold-water fishing.

Because they pose engineering difficulties and increase the cost, time and space needed for construction, river crossings were to be minimized. A number of major rivers had to be crossed and selecting

TABLE IX-4

FACTORS APPLIED IN SELECTING
NORTHERN BORDER PIPELINE ROUTE

- Physiography
  - Topography
  - Terrain Conditions
- Soil Conditions
  - Erodibility
  - Fertility
- Thinness of soil, depth to bedrock
  - Restoration properties
- Hydrology
  - Height of Water Table
  - River Crossings
  - Presence of other fresh water bodies--lakes, ponds, potholes
- Wildlife
  - Preservation of waterfowl habitats
- Sociologic Consideration
  - Preservation of cold water sport fishing
- Land Cover
  - Wetlands
  - Bedrock
  - Forests
  - Fragility of other vegetation
- Land Use
  - Public lands
  - Agriculture
  - Urban Areas
- Esthetics
  - Restoration of topographic relief
  - Visible scars of pipelines and constructions

points where it was feasible to do so, particularly under topographic and land use (urban and commercial development) constraints, provided a basic limitation on the practical options for route location.

Land use patterns both restricted the delineation of potential alternatives and also influenced selection of the single preferred route. These patterns included public lands set aside for conservation and other special use such as reservoirs, as well as urban and commercial developments that became more numerous and presented an increasing degree of restriction as the line moved east. In particular, Line 3 encountered conflict in land use as far west at the metropolitan area around Bismarck. East of the Mississippi, the availability of crossing sites along the river systems principally reflected industrial and residential patterns near the banks.

Selection Based on Critical Features

As noted above, no single alternative route was ideal nor did any one prove better in all regards than the others. To simplify and systematize selection of a preferred route, trade-offs were evaluated in terms of the critical features in four types of areas, as shown in Table IX-5, which is reproduced from the Environmental Assessment. These areas were badlands; rangelands; the "driftless" or unglaciated region in Iowa and Illinois; high water table areas; and conservation lands. Both badlands and rangelands represent highly eroded areas where, as a result of past erosion, slopes are unstable; thus, revegetation would be particularly difficult and further erosive effects can be expected.

Of the two types of regions, the virtually denuded badlands exhibit the critical features to a more significant degree than do the partially vegetated rangelands. The driftless region on either side of the Mississippi in Iowa and Illinois represents an area believed not to have been glaciated during the three latest glacial periods, where there has already been a high degree of erosion with thin soils and bedrock near the surface. Regions of high water table and conservation lands are self-explanatory.

Quantitatively, comparison among the alternative routes was made on a total mileage basis in terms of the distance each would occupy within these critical areas. As can be seen, Line 1 required less mileage than either Line 2 or 3 through all of the critical regions except the high water table and badlands areas. On this basis, plus the much greater environmental impact expected from Line 2 in the badlands and rangelands, Line 1 was judgmentally chosen. It was then slightly modified to reduce the extent through the badlands and rangelands and became the Preferred Route.

TABLE IX-5

CRITICAL FEATURE ANALYSIS

CRITICAL FEATURE	LINE 1	LINE 2	LINE 3	PROPOSED ROUTE
BADLANDS EXTREME SLOPE INSTABILITY HIGHLY EROSIVE EXTENSIVE GRADING REQUIRED REVEGETATION EXTREMELY DIFFICULT EROSION CONTROL EXTREMELY DIFFICULT RESTORATION LITTLE POSSIBILITIES AESTHETICS HIGHLY VISIBLE SCAR RIGHT-OF-WAY WILL REQUIRE LONG-TERM MAINTENANCE – LOGISTICS DIFFICULTIES	(APPROX MILEAGE) LITTLE MISSOURI BADLANDS (27) TOTAL MILEAGE (27)	(APPROX MILEAGE) LITTLE MISSOURI BADLANDS (4) YELLOWSTONE REDWATER RIVER DIVIDE (1) YELLOWSTONE RIVER GLENDIVE (10) TOTAL MILEAGE (15)	(APPROX MILEAGE) LITTLE MISSOURI GARRISON RESERVOIR (27) TOTAL MILEAGE (27)	(APPROX MILEAGE) LITTLE MISSOURI BADLANDS (7) TOTAL MILEAGE (7)
ROUGH RANGELANDS EXTENSIVE GRADING REVEGETATION DIFFICULT EROSION CONTROL DIFFICULT RESTORATION INCOMPLETE AESTHETICS VISIBLE SCAR LONG TERM MAINTENANCE ANTICIPATED	FRENCHMAN CREEK SYSTEM (12) MISSOURI RIVER (WOLF PT.) (3) YELLOWSTONE RIVER (FAIRVIEW S) (13) LITTLE MISSOURI RIVER (VICINITY) (7) OAHE RESERVOIR (BISMARCK SOUTH) (8) TOTAL MILEAGE (43)	FRENCHMAN CREEK SYSTEM (18) FORT PECK (VICINITY) (30) DIVIDE BETWEEN YELLOWSTONE AND REDWATER RIVER BASINS ( ) YELLOWSTONE RIVER (GLENDIVE) (25) LITTLE MISSOURI BADLAND (VICINITY) (11) GRAND MOREAU CHEYENNE RIVERS (15) MISSOURI RIVER (PIERRE) (15) TOTAL MILEAGE (114)	FRENCHMAN CREEK SYSTEM (35) MISSOURI RIVER (VICINITY OF CULBERTSON) (21) YELLOWSTONE RIVER (FAIRVIEW N) (3) LITTLE MISSOURI GARRISON RESERVOIR (VICINITY) (4) MISSOURI RIVER (BISMARCK) (1) TOTAL MILEAGE (64)	FRENCHMAN CREEK SYSTEM (18) MISSOURI RIVER (WILLISTON) (3) LITTLE MISSOURI BADLAND (VICINITY) (3) OAHE RESERVOIR (BISMARCK SOUTH) (8) TOTAL MILEAGE (32)
DRIFTLESS REGION REVEGETATION (GRASS) COMPLETE EROSION CONTROL DIFFICULT BLASTING REQUIRED RESTORATION INCOMPLETE AESTHETICS VISIBLE SCAR LOSS OF TIMBER LOGISTIC DIFFICULTIES LITTLE LONG TERM MAINTENANCE			DRIFTLESS REGION IOWA (80) ILLINOIS (40) TOTAL MILEAGE (120)	
HIGH WATER TABLE AREAS MOVEMENT OF HEAVY EQUIPMENT DIFFICULT PIPE BENDS REQUIRED PIPE WEIGHTS REQUIRED PRESERVATION OF NATURAL HYDROLOGY DIFFICULT RESTORATION COMPLETE LONG TERM MAINTENANCE NOT ANTICIPATED	COUTEAU DE MISSOURI (38) COUTEAU DE PRAIRIE (46) MINNESOTA (130) TOTAL MILEAGE (214)	COUTEAU DE MISSOURI (30) COUTEAU DE PRAIRIE (12) MINNESOTA ( ) TOTAL MILEAGE (42)	COUTEAU DE MISSOURI (38) COUTEAU DE PRAIRIE (36) MINNESOTA (84) TOTAL MILEAGE (158)	COUTEAU DE MISSOURI (38) COUTEAU DE PRAIRIE (46) MINNESOTA (130) TOTAL MILEAGE (214)
NATIONAL PARKS, FORESTS, WILDLIFE REFUGES	NATIONAL GRASSLAND RANGE (LITTLE MISSOURI RIVER) (25) UPPER MISSISSIPPI WILDLIFE REFUGE (1 5)	NATIONAL GRASSLAND RANGE LITTLE MISSOURI RIVER (4 5) GRAND RIVER (2) UPPER MISSISSIPPI RIVER WILDLIFE REFUGE (1 5)	NATIONAL GRASSLAND RANGE LITTLE MISSOURI RIVER (5) UPPER MISSISSIPPI WILDLIFE REFUGE (1 5)	NATIONAL GRASSLAND RANGE LITTLE MISSOURI RIVER (2) UPPER MISSISSIPPI WILDLIFE REFUGE (1 5)
MITIGATION	ADOPTION OF MODIFICATIONS TO BECOME PREFERRED ROUTE	LITTLE OR NO POTENTIAL MITIGATION OF INTERACTION WITH ABOVE CRITICAL FEATURE WITHOUT MARKEDLY INCREASING LENGTH OF PIPELINE	MITIGATION WOULD RESULT IN THE ADOPTION OF THE PREFERRED ROUTE ALIGNMENT	

Assessment

The pipeline has been quite recently proposed and no information is available on any action taken regarding its implementation. In determining the proposed location, a standard methodology appears to have been used that would be applicable to any very long line. Aerial photographs provide a convenient way to cover the very considerable area involved. Computerized methodology would have involved an enormous operation of data collection and organization.

In making final selection among the proposed routes, narrowing on the criterion of how each alternative would affect a set of critical areas seems to provide an effective decisionmaking tool. This approach provided a means of focusing the selection process on those features that were most significant and facilitating systematic comparison among the options. The result was choice of a route on a judgmental basis of least environmental impact. While necessarily somewhat subjective, the basis of the judgment made is systematic, structured, and easily interpreted.

There are no specific data available on which to conclude that a different line would have resulted from a choice based strictly on cost and engineering considerations. Such an event seems unlikely, however, in view of the extent to which the most vulnerable environmental features coincided with those offering particular construction difficulties. On a strictly quantitative basis of total miles of critical areas traversed, Line 2 would have been chosen over Line 1. Line 2 involves a total of about 181 miles of critical areas, as compared with 253 miles even for the Preferred Route. Thus, had greater emphasis been placed on minimizing crossing of high water table areas, Line 2 -- with minimum number of miles involving such areas -- would have been chosen.

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